HISTORICAL LIFE COURSE STUDIES

VOLUME 2
2015

EHPS
NETWORK

MISSION STATEMENT

HISTORICAL LIFE COURSE STUDIES

Historical Life Course Studies is the electronic journal of the *European Historical Population Samples Network* (EHPS-Net). The journal is the primary publishing outlet for research involved in the conversion of existing European and non-European large historical demographic databases into a common format, the Intermediate Data Structure, and for studies based on these databases. The journal publishes both methodological and substantive research articles.

Methodological Articles
This section includes methodological articles that describe all forms of data handling involving large historical databases, including extensive descriptions of new or existing databases, syntax, algorithms and extraction programs. Authors are encouraged to share their syntaxes, applications and other forms of software presented in their article, if pertinent, on the EHPS-Net website.

Research articles
This section includes substantive articles reporting the results of comparative longitudinal studies that are demographic and historical in nature, and that are based on micro-data from large historical databases.

Historical Life Course Studies is a no-fee double-blind, peer-reviewed open-access journal supported by the European Science Foundation (ESF, http://www.esf.org), the Scientific Research Network of Historical Demography (FWO Flanders, http://www.historicaldemography.be) and the International Institute of Social History Amsterdam (IISH, http://socialhistory.org/). Manuscripts are reviewed by the editors, members of the editorial and scientific boards, and by external reviewers. All journal content is freely available on the internet at http://www.ehps-net.eu/journal.

Editors: Koen Matthijs & Paul Puschmann
Family and Population Studies
KU Leuven, Belgium
hislives@kuleuven.be

The European Science Foundation (ESF) provides a platform for its Member Organisations to advance science and explore new directions for research at the European level. Established in 1974 as an independent non-governmental organisation, the ESF currently serves 78 Member Organisations across 30 countries. EHPS-Net is an ESF Research Networking Programme.

The European Historical Population Samples Network (EHPS-net) brings together scholars to create a common format for databases containing non-aggregated information on persons, families and households. The aim is to form an integrated and joint interface between many European and non-European databases to stimulate comparative research on the micro-level.
Visit: http://www.ehps-net.eu.

HISTORICAL LIFE COURSE STUDIES
VOLUME 2 (2015), 58-85 published 03-12-2015

Social Strata Differentials in Reproductive Behavior among Agricultural Families in the Krummhörn Region (East Frisia, 1720-1874)

Kai P. Willführ
Max Planck Institute for Demographic Research

Charlotte Störmer
Utrecht University

ABSTRACT

In this paper, we investigate how the reproductive behavior of families in the historical Krummhörn region was affected by their social status and by short-term fluctuations in their socioeconomic conditions. Poisson and Cox regression models are used to analyze the age at first reproduction, fertility, the sex ratio of the offspring, sex-specific infant/child survival, and the number of children. In addition, we investigate how fluctuations in crop prices affected infant and child mortality and fertility using Cox proportional regression models. We also include information about the seasonal climate that may have had an effect on crop prices, as well as on infant mortality via other pathways. We find that the economic upper class produced more infants and had more children who survived to adulthood than the lower social strata. While the upper class did not have lower infant and child mortality than the lower class, they had more surviving children because of their shorter birth intervals and lower female age at marriage. Crop prices did not affect mortality or fertility before 1820. From 1820 onwards, high crop prices were associated with increased child (but not infant) mortality and with extended inter-birth intervals. We believe this period-sensitive response to changes in the crop price was the result of a social transition that took place during our study period, in which relations between the classes went from being based on communal "table fellowships" (*Tischgemeinschaft*) to being based on capitalist employer/employee arrangements.

Keywords: Krummhörn (East Frisia), Reproductive Strategy, Economic Fluctuations, Crop Price, Infant Mortality, Child Mortality, Fertility

e-ISSN: 2352-6343
PID article: http://hdl.handle.net/10622/23526343-2015-0006?locatt=view:master

The article can be downloaded from here.

1 INTRODUCTION

Differences in life histories—i.e., differences in the timing of vital events and demographic outcomes—have been studied by scholars in various disciplines in recent decades, especially by historical demographers and economic and social historians (see, e.g., Bengtsson, Campbell & Lee 2004; Knodel 1988; Wrigley & Schofield 1989). The features of life histories that have been of greatest interest to historians and demographers are marital timing, fertility, and survival patterns. In addition to looking at the general trends in these features over time, scholars have examined the long-term and the short-term effects of economic constraints on these patterns (e.g., Dribe, Oris & Pozzi 2014; Galloway 1988; Skirbekk 2008).

At the same time, there is a growing body of literature that has been investigating from an anthropological and an evolutionary perspective the general differences in long-term (reproductive) behavior, as well as in short-term responses to environmental cues (e.g., Borgerhoff Mulder 1988; Hayward, Holopainen, Pettay & Lummaa 2012; Pettay, Helle, Jokela & Lummaa 2007). As evolutionary approaches are interdisciplinary, these studies take into account demographic, historical, socioeconomic, and ecological factors.

The concept of human behavioral ecology, which we are applying in the current study, is an evolutionary anthropological framework built on the assumption that selection favors reproductive behavior that maximizes fitness (reproductive success; see, e.g., (Cronk 1991). For all mammals, including humans, the reproductive success and the life course of each individual are dependent on several intrinsic and extrinsic factors and constraints that shape trade-offs through interactions in a multidimensional ecological continuum. Among species that live in social groups, the reproductive behavior and the reproductive decisions of the individual are always constrained by the individual's social position. This also holds true for humans in modern societies, as the socioeconomic conditions of families are often stable for many generations, especially in class-based societies or in environments in which social mobility is reduced. In contrast, in small-scale societies in which the division of labor is absent or is less developed, and in which economic power is not held by individuals (cf. in egalitarian hunter-gatherer societies), it is less likely that the inter-family differences in socioeconomic conditions would be determined by the economic system (Borgerhoff Mulder et al. 2009). In non-egalitarian societies, however, the socioeconomic conditions of families greatly depend on their social stratum. For example, the optimal reproductive behavior of the landless may be expected to be fundamentally different from that of the rich (Pettay et al. 2007). In general, persistent social stratification and social stratum-specific reproductive behavioral patterns arise if wealth (e.g., land, money, and company ownership) is heritable, and are reinforced if overproduction allows for an accumulation of wealth. These two trends are found in capitalist societies and their precursors. Therefore, even if members of different social strata are sharing the same geographical habitat (e.g., if agricultural workers are living on the farm of their employer), they are facing different social-status-specific constraints. Hence, they should follow different reproductive strategies in order to maximize their fitness/reproductive success.

These different reproductive strategies might lead to the development of life history traits that are characteristic of individuals with a given social status, such as specific average ages at marriage and first birth (Voland & Dunbar 1995), average numbers of births and surviving offspring (Störmer 2011), and average levels of parental investment in each child (cf. the Trivers-Willard hypothesis, Trivers 1974; Trivers & Willard 1973).

In this paper, we investigate from a behavioral ecology perspective how the reproductive behavior of families was affected by their social status and changes in their socioeconomic conditions. We examine the historical population of the Krummhörn region in East Frisia (northwestern Germany) of the 18th and 19th centuries, which can be characterized as a non-egalitarian, pre-capitalist agricultural society. As was mentioned above, it has often been shown that social success correlates with reproductive success; yet why this is the case is often unclear. This correlation may be attributed to two mechanisms that are not mutually exclusive. Elite families may reproduce more successfully than lower class families because they have better living conditions and/or because their offspring are better shielded from economic fluctuations. Based on these considerations, we seek to answer two main questions. First, are there differences between the reproductive parameters of families of different social strata, such as the number of children born, the number of children who survive to adulthood, the length of inter-birth intervals, infant and child mortality, the age at first marriage, and the sex ratio of offspring? Second, do dynamic economic processes have different effects on the short-term outcomes of families depending on their social class; and, if so, how? In order to answer these questions, we investigate how changes in crop prices affected infant and child mortality, as well as the average age at first marriage and the fertility of married women. We also include data on climatic conditions (using a seasonal temperature index) in our models to control for unobserved characteristics that might have affected infant mortality.

2 HYPOTHESES AND EXPECTATIONS

2.1 HYPOTHESIS 1: DIFFERENT SOCIAL STRATA PURSUE DIFFERENT REPRODUCTIVE STRATEGIES

We expect to find that wealth—or, more specifically, the extent of landownership—correlates with reproductive success over the long term. Families who owned farms large enough to allow for the production of agricultural commodities above the level of their personal requirements should have had more births and more children who survived to adulthood. Because the undivided land was bequeathed to a single son, while the other siblings were paid off (system of ultimogeniture, see Klindworth & Voland (1995) and material section below), we expect to find that among landowners the reproductive value of the individual child—and, consequently, the expected amount of parental per capita investment in the children (Trivers 1974)—was highly dependent on the child's sex (Trivers & Willard 1973), and on the number of older brothers and sisters who were alive at his or her birth.

Among the landless families and the families with subsistence-level production, we expect to find that the numbers of births and, consequently, of adult children, were lower than those of the upper class families. However, we cannot immediately predict to what extent the reproductive value of an individual offspring of a landless family was dependent on his or her sex and on the number of his or her older male and female siblings; or to what extent his or her sex influenced the parents' investment in the child. It might be argued that the reproductive value of individual children and the size of the parents' investment in each child were affected by two opposing mechanisms, which were not mutually exclusive. First, the labor provided by sons and daughters might have been beneficial for the parental household. Thus, the children were acting as "helpers at the nest" (Crognier, Baali & Hilali 2001), regardless of whether they worked directly in the parental household (e.g., looking after younger siblings) or contributed to the household budget by earning wages. Assuming this was the case, we may expect to find that the children were relatively old at their first marriage, and that this family structure was especially beneficial for children who grew up in a household with older siblings. The children who were born later benefited from the investments made by both their parents and their older siblings. In addition, some children of poor and low-ranking parents might have had the opportunity for upward social mobility. For example, a daughter might have been able to marry a partner with a higher social status because her chances on the matrimonial market correlated with her reproductive body traits (Pawłowski 2000). In such cases, we would expect to see a relatively low average age at first marriage among daughters, as female reproductive traits and age are negatively correlated.

2.2 HYPOTHESIS 2: THE EXTENT OF LANDOWNERSHIP CORRELATES WITH ECONOMIC INDEPENDENCE

Due to unstable or extreme weather conditions (droughts, floods), pest infestations, and other factors, the amount of available food among agricultural societies can fluctuate greatly over the years. A proxy that reflects food availability, at least to some extent, is the crop price, which is available for the Krummhörn region from 1746 until 1864 (see below). We expect to find that the crop price, as a measure of changes in living expenses (e.g., Galloway 1988), did not affect families of different social strata equally. The landless and the small farming families should have been more negatively affected in the short term by high crop prices and poor harvests, and should have experienced increased child mortality and reduced fertility (i.e., longer inter-birth intervals). In contrast, families with farms that were productive enough to feed the family even if the harvests were bad may be expected to have avoided malnutrition, and even to have profited from the situation if they were able to sell their agricultural commodities at higher prices (a situation which is henceforth referred to as the "crisis winner scenario").

3 MATERIAL AND DATA SELECTION

3.1 THE STUDY POPULATION

The data used in this study are based on family reconstitutions (see, e.g., Voland (2000) for a description of the methodology) from church records from the 18th to 19th centuries and tax rolls from the 18th century from the historical Krummhörn region. The Krummhörn was a small coastal region located in the far northwestern part of Germany, in East Frisia. During the 18th and 19th centuries, the Krummhörn had 33 parishes. The dataset includes 34,708 marriages and 80,486 birth records.

The Krummhörn region had very fertile marsh soil. Most people made their living by farming and dairying, and the population did not suffer from severe famines during the study period. However, due to the geographical position of the region, there was little room for the population to expand. The settlement of the area had been completed in the late medieval period (Ohling 1963), and there was no significant population growth over the study period (Voland & Dunbar 1995). From an ecological perspective, the region can therefore be described as a saturated habitat in which the population faced a local resource competition scenario (Voland 1995). Because access to land was limited, a stratified social structure arose among the population of the Krummhörn. At the one extreme there was a social upper class made up of large-scale farmers (farmers who owned more than 75 *grasen*; 1 *gras* = 0.36 hectare) and had both capital and status; while at the other end of the spectrum, there was a lower social class made up of small-scale farmers, tenants, craftsmen, and workers who were largely landless. According to our data, about 70 percent of the region's families in the 18th century either had no land at all or owned farms too small to ensure subsistence, and therefore worked for the large-scale farmers of the social upper class. About 15 percent of the population belonged to large-scale farming families (if only the families for whom the landownership status is known are considered). These elite families owned more than 75 percent of the farm land. The remaining 15 percent of the population did not belong to the elite, but owned estates that were big enough to sustain their families, and were therefore economically independent.

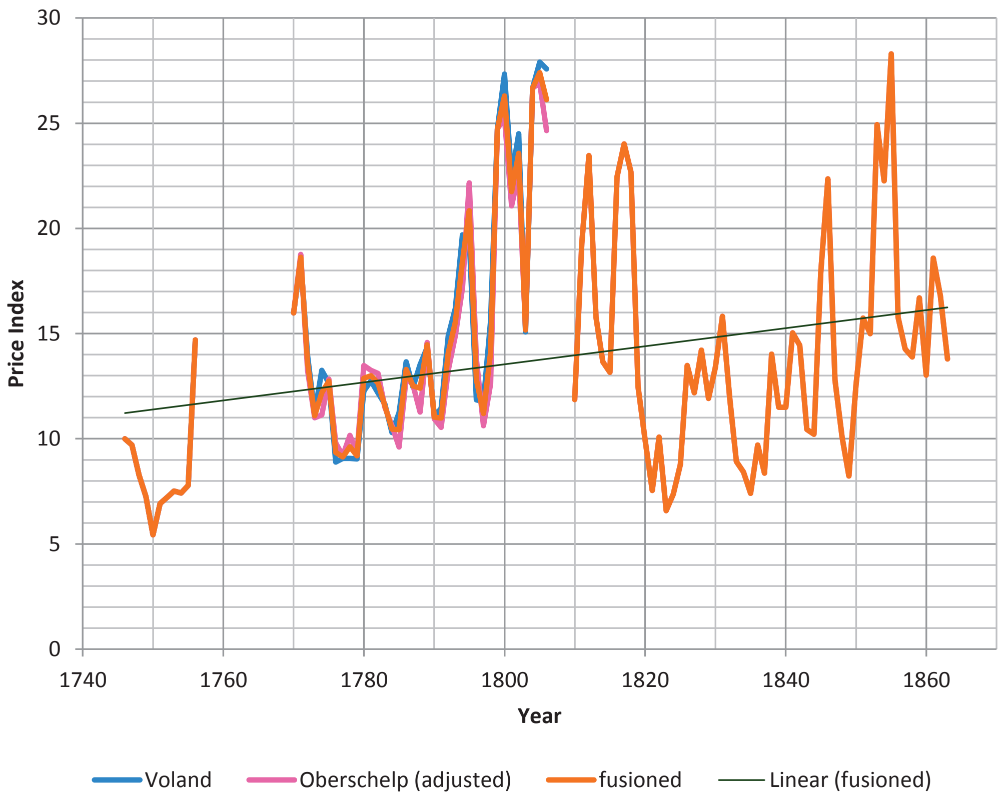
In this specific geographical and ecological context, the reproductive decisions of the population were primarily based on the desire to preserve wealth, and thus to prevent the extinction of the family lineage (Voland & Dunbar 1995). Conventionally, a form of ultimogeniture was practiced in which the youngest son inherited the undivided farm from the father (Klindworth & Voland 1995). All of the other offspring had to be compensated, often with cash. Daughters could expect to receive compensation amounts that were half the size of the amounts received by sons. As a consequence of these inheritance practices, families in the Krummhörn were relatively small and had relatively high ages at first marriage and first birth. Because of the delay in reproduction, birth rates were low, especially among families of the social upper class.

3.2 CROP PRICES

Annual crop prices are available from two different sources, the study periods of which partly overlap. In both cases the prices are adjusted for changes in units and currency, but not for price trends (cf. Oberschelp 1986). Annual rye prices have been collected by Eckart Voland, and are available for the periods of 1746 to 1756 and 1770 to 1806. This study is the first to use these data. Further prices for four types of grain, including rye, have been collected by Oberschelp (Oberschelp 1986) and are available for the period of 1771 to 1863, with missing information for the years 1799, 1804, and 1807-1809. The annual crop prices for rye, oats, and barley were calculated from November's and December's average prices at the market in the town of Emden, which is just south of the Krummhörn region. November's and December's prices provide a good reflection of the annual crop yield, and are therefore suitable as a proxy for food supply. The price for wheat was taken from the market in the city of Norden, which is north of the region. All four types of grain were planted in the Krummhörn region, but rye was the most important grain (Oberschelp 1986). For this reason, we have chosen to use the price of rye only as the proxy for annual food supply. It is likely that rye was dominant in the Krummhörn region because the grain is relatively robust, and was therefore best suited to the often rough coastal weather conditions in the area.

We pool the rye prices from the two sources in order to create a single price index. First, we adjust the prices collected by Oberschelp by multiplying all of the data points by the value 4.6 so that they match the prices collected by Eckart Voland. Although Voland and Oberschelp used different sources, the prices differ only marginally (see Figure 1). To produce the price index, we take the average of the prices from the two sources (when available) for the years 1771-1798, 1800-1803, and 1805-1806; the prices provided by Voland for the years 1746-1756 and 1770; and the prices provided by Oberschelp for the years 1810-1863. As the trend line in Figure 1 shows, the rye price increased over the study period. To test whether this trend has a significant effect on the results, we ran all of the models that include the annual crop price with both the uncorrected and the trend removed price index. As the results differed only marginally, we decided to use the rye price index as collected by Oberschelp and Voland (we will address this choice and its implications in the discussion).

Figure 1 *The annual crop prices collected by Voland (1746-1756 and 1770-1806) and by Oberschelp (1771-1863)*



Explanation: The prices collected by Oberschelp have been adjusted to match the prices collected by Voland (multiplied by 152), and have been converted to a single price index covering the period 1746 to 1863; with missing data for the years 1757-1769, 1799, 1804, and 1807-1809. In the period (1771-1806) for which data are available from both sources, the collected prices have almost the same value.

3.3 CLIMATE DATA

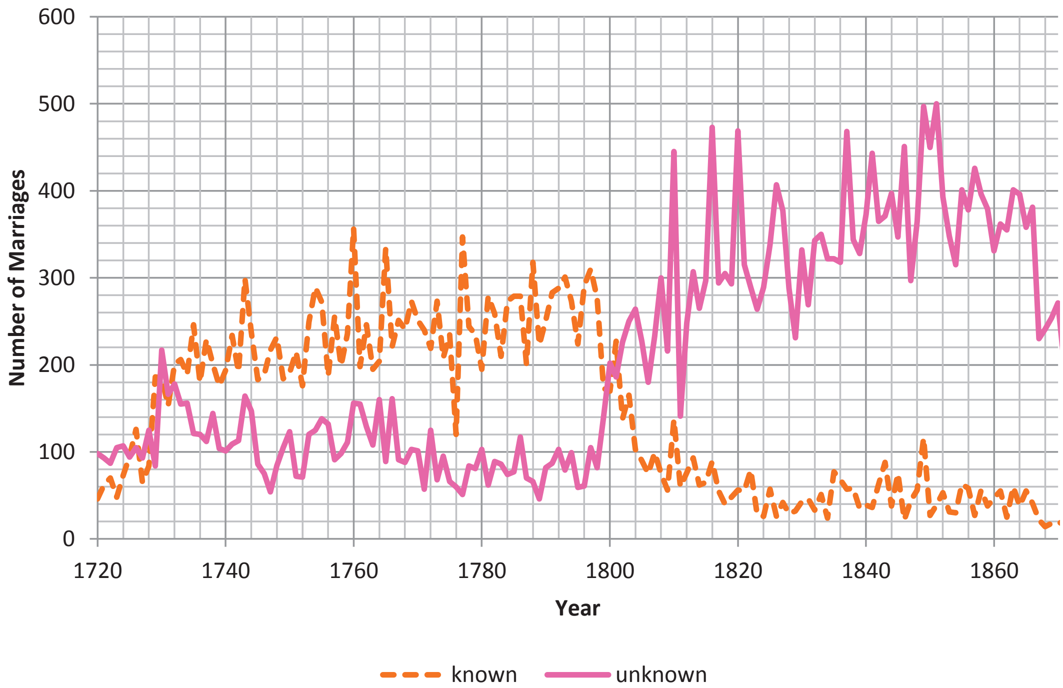
As was mentioned above, the Krummhörn region reached population saturation in the late medieval period. Because of the intensive level of agricultural use of the countryside, any natural climate records that might otherwise have been available were destroyed. There are, for example, no terrestrial sediments from our study period that remained untouched, and there are no trees left that are old enough to allow for a dendrochronological climate reconstruction. We have therefore chosen to use the climate reconstruction for central Europe that was compiled by Glaser and Riemann (2010) using several data sources. For our study period, monthly temperature indices are available. We use the three-month arithmetic mean (e.g., springtime=(Index for March + Index for April + Index for May) / 3; summertime=(Index for June + Index for July + Index for August) / 3; etc.) of these indices in order to create seasonal indices and include them in the models that measure infant and child mortality (see methods section).

3.4 DATA SELECTION AND STUDY PERIODS

In addition to lacking complete information on the price of rye, we face two more limitations related to time. There are temporal constraints on the information from the church books, as well as from the tax rolls. The data in the church records from before 1720 are often incomplete and biased, as most of the marriages that were recorded were of individuals who were considered important and had a high rank in society. The offspring of couples who married before 1720 are therefore excluded from the analysis. After 1874, the church was no longer responsible for recording births and deaths, as this responsibility was transferred to the *Standesämter* by the (civil) administration of the German Reich. Unfortunately, the records of the *Standesämter* are not yet available. We therefore had to treat all information after 1874 as censored, even though there are (incomplete) records up to the middle of the 20th century.

As we noted above, tax rolls from the 18th century provide us with information on the land ownership status on many families. Unfortunately, such information is missing for most of the 19th century. As a result of the social classification of the historical Krummhörn population, determining the land ownership status of families is not possible after 1810. The comparison of the different social strata is therefore limited to individuals who were offspring of marriages contracted between 1720 and 1810 (Figure 2). The timeline in Figure 3 provides an overview of the study periods and shows the data limitations that arose from the constraints mentioned above.

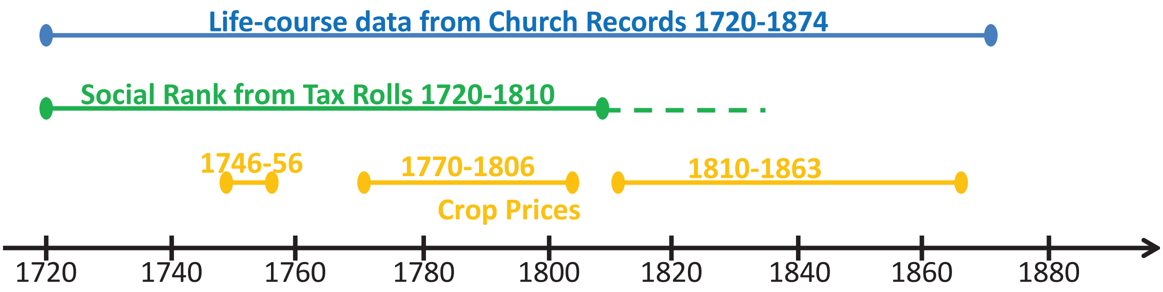
Figure 2 *The annual number of marriages contracted split into groups of known and unknown landownership status.*



Explanation: The share of marriages for which the landownership status is known drops significantly at the beginning of the 19th century due to the reduced availability of tax roll data.

In addition, we only include families whose reproductive histories are known; i.e., for whom there are reliable records on the beginning of the marriage (the exact date of the marriage is known) and the end of the marriage (the parents' dates of death are known). In cases that fulfill these criteria, we can assume that all of the births of the family have been recorded in the church registers. We restrict the sample to these families as cases in which the information on the number of births is incomplete might bias the results. However, we are aware that restricting the analyses to families with known reproductive careers will exclude a certain share of the families who migrated, and thus did not spend their entire lives within the study area. Beise (2001) conducted a comprehensive analysis of the migration behavior of the people of the Krummhörn region. He concluded that there are no general differences between the migrating and the residential segments of the population. We therefore have no reason to believe that this selection criterion biases the results, although we cannot entirely rule out this possibility.

Figure 3 *This timeline illustrates the temporal data availability of church records (in blue), of crop prices (in yellow), and of families' land ownership status (social rank) determined by the tax rolls (in green).*



Explanation: The three data sources overlap only partly; as a consequence, analyses that include both the social rank of families and the crop prices cover a rather small period.

The total number of children born to a family is dependent, among other factors, on paternal and maternal survival. A woman cannot fully exploit her reproductive potential if she (or her spouse) dies before she reaches menopause. For this reason, it is sometimes useful to compare specific characteristics (e.g., the number of births or the number of adult offspring, see below) only between families in which both spouses survived the wife's 45th birthday, especially in contexts in which adult mortality was high. Such families are referred to as "complete" families in this article.

3.5 CATEGORIZATION OF SOCIAL STRATA

We categorize the cases that remain after data selection into five groups based on their land ownership status. Families who owned more than 75 *grasen* are classified as "large-scale farmers" (Beise 2001), families who owned between 10 and 75 *grasen* are assigned to the "mid-scale farmers" group, while families who owned less than 10 *grasen* are categorized as "small-scale farmers." Families who had no property are classified as "landless," and families for whom the level of land ownership was unknown are placed in the "unknown" group.

4 METHODS

4.1 SET OF ANALYSES I - GENERAL DIFFERENCES BETWEEN THE SOCIAL STRATA

To investigate whether social status affected infant and child mortality, fertility, and the children's ages at first marriage, we use a number of different statistical methods (e.g., Poisson and Cox regression models) that allow us to control for observed confounding variables. We use Poisson regression models to estimate the total number of children born to families and the total number of children who survived to adulthood (their 15th birthday). In order to control for observed confounding variables, the Cox proportional hazard regression models (Cox 1972) are used to estimate infant and child mortality (from birth to the age of one), and the girls' and the boys' ages at first marriage. In addition to the indicators for social strata, we include the following child- and family-specific (time invariant) covariates:

Family-specific covariates
- Number of older brothers and sisters alive at the child's birth
- Maternal and paternal ages at the child's birth

Child-specific covariates
- Child's sex
- Child's birth cohort
- Child's birth rank (order)

Because child mortality changed in the Krummhörn region over the study period, we include the birth cohort (coded in decades) in our models. The other control variables are included because child survival is often affected by sex and birth order (Rutstein 1984), and because there is evidence that both the maternal (Myrskylä & Fenelon 2012) and the paternal (Arslan in prep; Zhu, Vestergaard, Madsen & Olsen 2008) ages at conception (deduced from their ages at the birth of the child) are associated with infant survival.

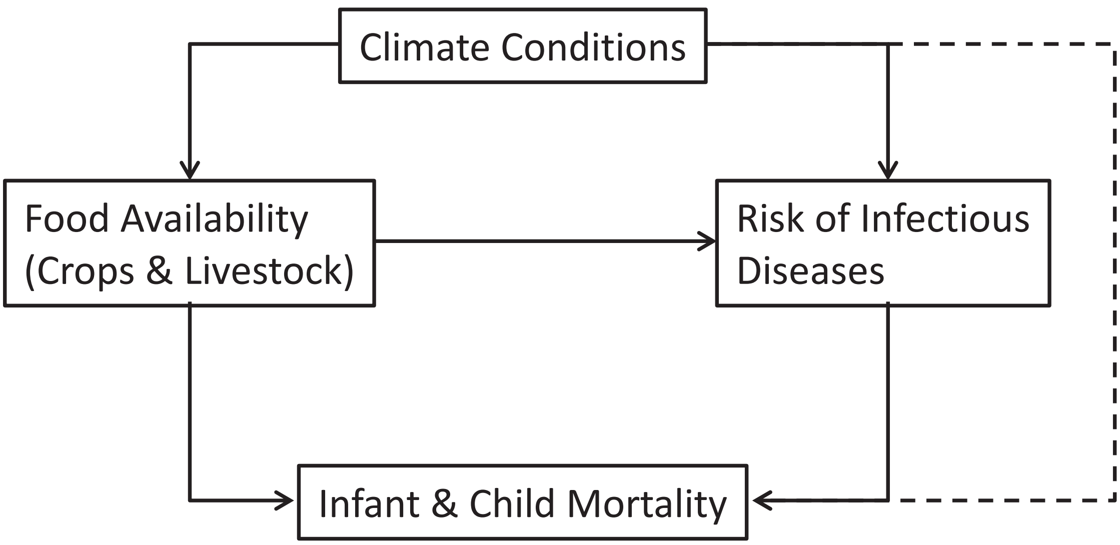
4.2 SET OF ANALYSES II - SHORT-TERM MORTALITY AND THE FERTILITY RESPONSES OF THE SOCIAL STRATA TO CHANGES IN THE PRICE OF RYE

4.2.1 INFANT AND CHILD MORTALITY

We use proportional Cox regression models to estimate infant mortality (between birth and the first birthday) depending on the price of rye, the temperature indexes, and child- and family-specific controls; separately for each season. A Cox proportional regression approach is also used to estimate child mortality between the child's first and 15th birthdays. For the analyses, each meteorological season experienced by an individual between his or her first and 15th birthdays is coded as an observation episode that contains, in addition to time-invariant confounders (see Set of Analyses I), time-varying information about the price of rye and the seasonal temperature index. This approach allows us to investigate how changes in the price of rye and the seasonal temperature affect child mortality, and to test for interactions between a child's social stratum and the price of rye.

In our opinion, studies that investigate the association between changes in crop prices and mortality benefit from integrating climate information into their models. There are many direct and indirect pathways through which climate conditions could affect mortality, including modulator effects in disease load. We thus assume that there was a strong relationship between climate conditions and the price of rye (see Figure 4).

Figure 4 *Schematic relationship between climate conditions and child mortality*



Explanation: Climate conditions might affect food availability and/or modulate the risk of infectious diseases. In extreme cases, climate conditions might have direct effects on mortality.

Four different model setups are applied to estimate the impact of the price of rye on infant and child mortality. Model 1 includes all of the years for which the rye price is known (1746-1756, 1770-1806, 1810-1863), whereas Model 2 excludes the period before 1820. For the reasons explained above, Models 1 and 2 cannot include any information regarding social status because this is only possible for marriages that have been contracted between 1720 and 1810. We created Model 2 to reflect the substantial changes in East Frisia's political and social landscape after the Congress of Vienna in 1815. First, the economic situation relaxed after the Napoleonic Wars as the Krummhörn region became a part of the Kingdom of Hanover (before the East Frisian economy began to suffer acutely under Napoleon's

Continental System (Grab 2003). Second, the relationship between the large-scale famers and their workers changed at the beginning of the 19th century. Before 1820, "Tischgemeinschaften" (table fellowships) were common (Arends 1818-1820; Beise 2001). The large-scale farmers felt responsible for their workers and shared a table with them. In the first half of the 19th century, this social arrangement disappeared and was replaced by a capitalist hire-and-fire mentality.

Model 3 includes the family's social rank, and is therefore restricted to individuals who were born within marriages that were contracted between 1720 and 1810. Finally, Model 4 includes the same cases and covariates as Model 3, but additionally estimates the interaction between changes in the price of rye and the child's social status.

4.2.2 FERTILITY AND THE AGE AT FIRST MARRIAGE

Changes in the rye price might affect both the fertility of married women, as well as the timing of marriage for nubile boys and girls. To test the impact on fertility, we model the female reproductive life history on an individual level by applying so-called multiple exit Cox regression modeling (Lin 1994). We follow the reproductive behavior of married women (with a living husband) of fertile ages (<45 years) after the birth of their first child and until their 45th birthday. We choose the date of the first childbirth and not the date of marriage as the starting point, because in historical populations the first childbirth is often associated with marriage, and reflects a couple's fecundity instead of their reproductive decision-making, which is the topic we are interested in. Episodes of observations are characterized by (annual) changes in the rye price as well as by the birth of children. Episodes in which the crop price is missing (see Figure 3) or in which the mother was not living with her husband (e.g., because she was widowed) are excluded from the analysis. The sample therefore consists exclusively of women who had the potential to have another child, as environmental and ecological disturbances that could have had an impact on reproduction would have affected this segment of the population in particular. A similar study approach was used in Quaranta (2013). As was done in these mortality analyses, we created four models for studying fertility. Model 1 includes all of the available episodes, but does not control for social stratum. Model 2 is similar to Model 1, but the period before 1820 is excluded from the analysis. Model 3 includes the information about the maternal social stratum, and Model 4 additionally estimates the interaction between the social rank and changes in the rye price. All four of the models include information about the mother's birth cohort (in decades), her age at first childbirth (categorical), the number of the childbirth or the parity (time varying), and how many living daughters and sons the mother had (time varying).

To estimate the impact of changes in the price of rye on the age at first marriage, we follow boys and girls from their 15th birthday onward until their first marriage. The sexes are analyzed separately, and individuals who did not marry before they died are included as censored cases. In this case as well, we apply the four models described above. All four of the models control for the individual's birth rank and birth cohort (in decades), as well as for the number of older sisters and brothers the individual had at birth and at age 15.

All of the Cox regressions used in this study are tested for proportional hazard assumptions, and the models are corrected when proportionality assumptions are violated.

5 RESULTS

5.1 SET OF ANALYSES I - GENERAL DIFFERENCES BETWEEN THE SOCIAL STRATA

In Table 1, we provide descriptive statistics about the sample sizes and the other traits of interest of the different social strata, including the average total number of births, the total number of adult children, the infant and child mortality rates, the inter-birth intervals, and the sex ratio at birth and at the first birthday.

Results from the Poisson models that are used estimate the total number of births of the different social strata are given in Table 2. The mid-scale farmers did not differ substantially from the large-scale

Table 1 *Descriptive statistics for the reproductive parameters of the different social strata in the Krummhörn population.*

		All Families					
		Total Number of Births* (still births excluded)			Total Number of adult children*		
Social rank	**N families**	N Births	MEAN	SD	N adults	MEAN	SD
Large-scale farmers	448	2,085	4.654	3.126	1,494	3.335	2.354
Mid-scale farmers	508	2,158	4.248	3.038	1,526	3.004	2.001
Small-scale farmers	556	2,207	3.969	2.997	1,570	2.824	2.188
Landless	1,900	7,686	4.045	2.759	5,545	2.918	2.063
Unknown	1,838	6,523	3.549	2.671	4,870	2.615	2.037
Total	**5,250**	20,659	3.935	2.834	14,942	2.846	2.117

		Complete Families					
		Total Number of Births* (still births excluded)			Total Number of adult children*		
Social rank	**N families**	N Births	MEAN	SD	N adults	MEAN	SD
Large-scale farmers	176	893	5.074	3.316	644	3.659	2.402
Mid-scale farmers	194	979	5.046	3.122	676	3.485	2.210
Small-scale farmers	197	866	4.396	2.987	629	3.193	2.248
Landless	798	3,578	4.495	2.812	2,555	3.210	2.104
Unknown	687	2,894	4.213	2.783	2,155	3.137	2.154
Total	**2,052**	9,210	4.493	2.908	6,659	3.248	2.175

	Infant Mortality*		Child Mortality (1st -15th birthday)*		Age at 1st Marriage (girls)			Age at 1st Marriage (boys)		
Social rank	N	%[1]	N	%[1]	N	MEAN	SD	N	MEAN	SD
Large-scale farmers	299	14.3	322	15.4	490	24.987	5.423	365	30.204	7.118
Mid-scale farmers	317	14.7	348	16.1	437	25.524	5.982	370	29.795	6.020
Small-scale farmers	314	14.2	374	16.9	420	26.073	5.283	349	28.976	5.794
Landless	982	12.8	1,297	16.9	1,408	26.649	5.186	1,418	28.191	5.276
Unknown	921	14.1	974	14.9	1,157	26.757	5.366	1,062	28.925	5.624
Total	2,833	13.7	3,315	16.0	3,912	26.285	5.407	3,564	28.859	5.758

	Inter-birth intervals[2]			Sex ratio at birth			Sex ratio at 1st birthday		
Social rank	N	MEAN	SD	N boys	N girls	ratio	N boys	N girls	ratio
Large-scale farmers	1,612	2.492	1.102	1,061	1,042	1.018	875	897	0.975
Mid-scale farmers	1,705	2.559	1.194	1,161	1,038	1.118	968	866	1.118
Small-scale farmers	1,733	2.729	1.337	1,161	1,091	1.064	953	934	1.020
Landless	5,988	2.784	1.385	4,086	3,775	1.082	3,449	3,241	1.064
Unknown	4,810	2.665	1.272	3,343	3,293	1.015	2,752	2,818	.977
Total	15,848	2.688	1.303	10,812	10,239	1.056	8,997	8,756	1.028

* - Note that due to missing data the number of adult children listed in this table does not necessarily equal the difference between the number of births and the number of dead infants and children.

[1] – Pertaining to the number of births.

[2] – Corrected for twin births.

farmers. The small-scale farmers (coefficient=-0.058+), the landless families (coefficient=-0.077***), and the families for whom the level of land ownership was unknown (coefficient=-0.176***) had fewer children than large-scale farming families. This is also found to be the case if only complete families are included in the model (coefficients=-0.104*, -0.123*** and -0.186***). The results of the Poisson models, which are given in Table 3, indicate that this lower level of fertility among the small-scale farming families, the landless families, and the families for whom the level of land ownership is unknown meant that these families had fewer children who reached adulthood (>15 years). The small-scale farmers (coefficient=-0.077+; -0.103+ in complete families), the landless families (coefficient=-0.095**; -0.152** in complete families), and the families for whom the level of land ownership was unknown (coefficient=-0.170***; =-0.170*** in complete families) had significantly fewer adult children than the large-scale farmers.

The results from the Cox proportional hazard regression models that estimate infant mortality are given in Table 4. The results of the model, which include both sexes, indicate that infant mortality was lower among the children of the landless than among the reference group (large-scale famers; HR=0.881+). The models that estimate infant mortality separately for the sexes reveal that this gap is attributable to lower male mortality (HR=0.844*) and not to differences in female mortality (HR=0.933$^{n.s.}$). Table 5 displays the results from the Cox regression models that estimate child mortality between the first and the 15th birthdays. The models indicate that mortality during childhood was neither social stratum- nor sex-specific.

The results from the Cox proportional hazard regression models that are used to estimate the length of inter-birth intervals are given in the last row in Table 4. The inter-birth intervals among the small-scale farmers (HR=0.882***), among the landless families (HR=0.859***), and among the families for whom the level of landownership was unknown (HR=0.892***) were longer than those of the large-scale farmers.

Table 2 *Results from the Poisson regression model estimating the total number of births among families of different social strata.*

	All Families	**Complete Families**
N families	3,765	1,730
LR chi2	751.19	373.96
Prob > chi^2	.0000	.0000
Pseudo R^2	.0424	.0457
Social rank		
Large-scale farmers (ref.)	1	1
Mid-scale farmers	.007	-0.011
Small-scale farmers	-0.058+	-0.104*
Landless	-0.077***	-0.123***
Unknown	-0.176***	-0.186***
Control variables		
Mother's birth cohort	.242***	.258***
Father's birth cohort	.063***	.078***
Marriage cohort	-0.322***	-0.340***
Constant	5.483***	3.166**

*** p < 0.001; ** p < 0.01; * p < 0.05; + p < 0.1
Childless couples are excluded from the analysis.

Table 3 *Results of the Poisson regression model estimating the total number of adult children (>15 years) among families of different social strata.*

	All Families	Complete Families
N families	3,765	1,730
LR chi2	457.48	237.11
Prob > chi²	.0000	.0000
Pseudo R²	.0301	.0334
Social rank		
Large-scale farmers (ref.)		
Mid-scale farmers	-0.022	-0.064
Small-scale farmers	-0.077+	-0.103+
Landless	-0.095**	-0.152**
Unknown	-0.170***	-0.170***
Control variables		
Mother's birth cohort	.230***	0.256***
Father's birth cohort	.059***	0.064***
Marriage cohort	-0.298***	-0.315***
Constant	3.613***	1.481

*** p < 0.001; ** p < 0.01; * p < 0.05; + p < 0.1
Childless couples are excluded from the analysis.

Table 4 *Results from the Cox proportional hazard regression modeling infant mortality and inter-birth intervals.*

Mortality	Infant Mortality	Male Infant Mortality	Female Infant Mortality	Inter-Birth Intervals
N individuals (N death and N births, respect.)	20,279 (2,634)	10,366 (1,447)	9,863 (1,187)	3,921 (15,222)
Log likelihood	-25,868.471	-13,225.788	-10,814.93	-118,517.78
LR chi²	138.67	96.96	55.06	1710.48
Prob > chi²	.0000	.0000	.0017	.0000
Hazard Ratios				
Social rank				
Large-scale farmers (ref.)	1	1	1	1
Mid-scale farmers	.994	.910	1.113	.982
Small-scale farmers	.997	1.006	.988	.882***
Landless	.881+	.844*	.933	.859***
Unknown	.974	.990	.965	.892***
Sex (female)	.850***	N/A	N/A	N/A
Birth cohort	.997	.994	1.000	.999
Birth rank	1.109***	1.123***	1.093***	1.149***
Next older sibling dead?				1.350***
Number of older sisters alive at birth				
0 (ref.)	1	1	1	1
1	.891*	.909	.868+	.999
2	.775**	.739**	.816+	1.045
3+	.689***	.675**	.699*	1.156***

Table 4 continued on next page

Mortality	Infant Mortality	Male Infant Mortality	Female Infant Mortality	Inter-Birth Intervals
Hazard Ratios				
Number of older brothers alive at birth				
0 (ref.)	1	1	1	1
1	.968	.946	.987	1.019
2	.808***	.777*	.848	1.063*
3+	.682***	.582***	.807	1.077+
Maternal age at birth				
– 20	1.603*	1.889*	1.319	2.596***
20 – 30 (ref.)	1	1	1	1
30 – 35	1.066	1.014	1.139	.762***
35 – 45	1.055	1.011	1.108	.545***
+45	.959	1.044	.889	.303***
Unknown	.976	.910	1.064	.694***
Paternal age at birth				
– 20	.812	.661	1.040	1.919
20 – 30	1.001	.927	1.113	1.213***
30 – 40 (ref.)	1	1	1	1
40 – 50	.978	.912	1.080	.801***
50 – 60	1.184	1.086	1.320	.635***
+60	.808	.762	1.043	.872
Unknown	.940	.892+	1.013	.904***
Inter-Birth-Interval				N/A
first born (ref.)	1	1	1	
3+ years	.703***	.741**	.667**	
2-3 years	.681***	.682***	.688**	
1-2 years	.838*	.828+	.860	
0-1 year	1.263	1.647**	.820	
Unknown (due to missing data)	.747*	1.035	.441**	

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; + $p < 0.1$

All models have been tested for the proportional hazard assumption. In no case was this assumption violated.

Table 5 *Results from the Cox proportional hazard regression modeling child mortality (1st to 15th birthday).*

Mortality	Child Mortality	Mortality of Boys	Mortality of Girls
N individuals (N death)	17,626 (3,315)	8,919 (1,675)	8,676 (1,634)
Log likelihood	-23,547.044	-10,753.528	-10,443.959
LR chi²	33.01	22.47	33.79
Prob > chi²	.1038	.4919	.0683
Hazard Ratios			
Social rank			
Large-scale farmers (ref.)	1	1	1
Mid-scale farmers	.943	.943	.939
Small-scale farmers	1.007	.969	1.042
Landless	.994	.943	1.059
Unknown	.932	.943	.932

Table 5 continued on next page

Mortality	Child Mortality	Mortality of Boys	Mortality of Girls
Hazard Ratios			
Sex (female)	1.031	N/A	N/A
Birth cohort	1.014+	1.015	1.013
Birth rank	.993	.998	.987
Number of older sisters alive at birth			
0 (ref.)	1	1	1
1	1.020	1.054	1.007
2	1.036	0.944	1.126
3+	1.037	1.077	1.034
Number of older brothers alive at birth			
0 (ref.)	1	1	1
1	1.092+	1.079	1.100
2	1.063	1.112	1.016
3+	1.044	0.896	1.229
Maternal age at birth			
– 20	0.835	0.825	0.847
20 – 30 (ref.)	1	1	1
30 – 35	1.091	1.092	1.085
35 – 45	1.103	1.130	1.070
+45	0.673	0.683	0.690
Unknown	1.116*	1.077	1.143+
Paternal age at birth			
– 20	1.472	1.738	1.325
20 – 30	0.943	0.942	0.951
30 – 40 (ref.)	1	1	1
40 – 50	1.025	1.065	0.985
50 – 60	1.220	0.925	1.776**
+60	0.739	0.481	5.851+
Unknown	1.044	1.081	1.030

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; + $p < 0.1$

All models have been tested for the proportional hazard assumption. In no case was this assumption violated.

5.2 SET OF ANALYSES II - SHORT-TERM MORTALITY AND THE FERTILITY RESPONSES OF THE SOCIAL STRATA TO CHANGES IN THE PRICE OF RYE

5.2.1 INFANT AND CHILD MORTALITY

The results from the Cox proportional hazard regression models that estimate season-specific infant mortality are given in Tables 6 and 7. Only Model 2 indicates that infant mortality during winter was increased by high rye prices after 1820 (HR=1.047*; Table 7). In no other season were changes in the price of rye associated with infant mortality. Moreover, there is no evidence that there was an effect for the interaction between the crop price and social rank. Interestingly, high temperatures were associated with increased infant mortality in summer and in autumn (Tables 6 and 7).

The results from the Cox proportional hazard regression models that estimate child mortality are given in Table 8. Model 2 indicates that child mortality was higher when the rye prices were high after 1820 (HR=1.076***). The interaction term indicates that this effect tended to be smaller during summer than during the reference category (winter) (HR=0.965+). Models 3 and 4, which include only those children who were born to families established between 1720 and 1810, do not show an effect of the

Table 6 *Results from the Cox regression models estimating the impact of the rye price on infant mortality in spring and in summer*

	Spring (March 1 – May 31)				Summer (June 1 – August 31)			
Model	1	2	3	4	1	2	3	4
N individuals (N death)	19,614 (586)	7,151 (176)	12,145 (408)	12,145 (408)	20,575 (502)	7,490 (145)	12,720 (354)	12,720 (354)
Log likelihood	-5,041.1209	-1,329.4996	-3,315.6066	-3,310.7667	-4,221.6758	-1,072.3513	-2,807.9042	-2,804.1477
LR chi²	22.43	7.02	19.05	28.73	30.55	11.98	15.16	20.67
Prob > chi²	0.0212	0.7971	0.2113	0.0703	0.0013	0.3648	0.4403	0.3554
Hazard Ratios								
Rye price	.995	.961+	.990	1.003	.997	.998	.993	.988
Temperature Index	.927	1.144	.884+	.881+	1.137*	1.124	1.169*	1.174*
Social rank	N/A	N/A			N/A	N/A		
Large-scale farmer (ref.)			1	1			1	1
Mid-scale farmer			.746	.357+			1.115	1.129
Small-scale farmer			.895	1.219			.920	.799
Landless			.772	.862			.883	.580
Unknown			.741	1.356			.973	1.381
Interaction social rank*rye price	N/A	N/A	N/A		N/A	N/A	N/A	
Large-scale farmer (ref.)				1				1
Mid-scale farmer				1.051				.999
Small-scale farmer				.978				1.011
Landless				.992				1.029
Unknown				.958				.975
Sex (female)	1.051	.665+ (t=1.003**)	1.070	1.070	.889	.833	.912	.913
Birth cohort	.961**	1.160+	1.006	1.005	.947**	.934	.988	.993
Next older sibling dead?	1.330+	.904	1.414**	1.407**	1.179	1.189	1.172	1.163
Number of older brothers at birth								
0 (ref.)	1	1	1	1	1	1	1	1
1	1.072	.892	1.105	1.100	1.077	1.248	.992	.987
2	.982	.981	.978	.966	.985	1.016	.951	.939
3+	1.198	1.072	1.168	1.149	1.070	1.796+	.891	.878
Number of older sisters at birth								
0 (ref.)	1	1	1	1	1	1	1	1
1	1.029	.976	.997	.996	.974	.858	1.039	1.032
2	1.030	1.183	.898	.897	.949	1.032	.854	.843
3+	1.160	1.332	1.005	.998	.924	.541	1.027	1.009

rye price on child mortality (HRs=0.991 and 0.999). Furthermore, Model 4 does not show an effect for the interaction between changes in the price of rye and social rank. In all four of the models, the interaction term between temperature index and season indicates that warm summers were associated with increased child mortality (HRs=1.236**, 1.239*, 1.207*, 1.207*). Models 1 and 3 indicate that warm autumns were also associated with increased mortality (HRs=1.240** and 1.367***).

Table 7 *Results from the Cox regression models estimating the impact of the rye price on infant mortality in autumn and in winter.*

	Autumn (September 1– November 30)				**Winter (December 1 – February 28)**			
Model	1	2	3	4	1	2	3	4
N individuals (N death)	20,584 (604)	7,417 (146)	12,720 (433)	12,720 (433)	20,654 (643)	7,459 (154)	12,734 (476)	12,734 (476)
Log likelihood	- 5,131.26 57	- 1,096.32 22	- 3,554.66 41	- 3,551.98 47	- 5,476.70 23	- 1,147.12 46	- 3,837.12 12	- 3,835.64 17
LR chi²	72.04	12.14	37.45	42.81	53.03	20.20	19.75	22.71
Prob > chi²	0.0000	0.3529	0.0011	0.0014	0.0000	0.0426	0.1817	0.2503
Hazard Ratios								
Rye price	1.000	1.018	.984	.956	1.006	1.047*	.984	1.007
Temperature Index	1.123*	1.129	1.124+	1.130+	.915+	.907	.918	.919
Social rank	N/A	N/A			N/A	N/A		
Large-scale farmer (ref.)			1	1			1	1
Mid-scale farmer			1.119	1.605			1.050	1.422
Small-scale farmer			1.211	.972			.813	1.838
Landless			.933	.591			.787	.963
Unknown			.995	.582			.948	1.404
Interaction social rank*rye price	N/A	N/A	N/A		N/A	N/A	N/A	
Large-scale farmer (ref.)				1				1
Mid-scale farmer				.970				.976
Small-scale farmer				1.018				.938
Landless				1.036				.985
Unknown				1.042				.972
Sex (female)	.901	.985	.907	.906	.985	.743	1.020	1.019
Birth cohort	.906***	.971	.936*	.940*	.913***	.856+	.975	.976
Next older sibling dead?	1.107	1.536+	1.014	1.017	.923	1.171	.872	.869
Number of older brothers at birth								
0 (ref.)	1	1	1	1	1	1	1	1
1	.984	.696+	1.119	1.122	1.107	1.210	1.012	1.012
2	.844	.748	.893	.898	1.249+	1.356	1.163	1.164
3+	.823	.772	.793	.798	1.081	1.651	.941	.938
Number of older sisters at birth								
0 (ref.)	1	1	1	1	1	1	1	1
1	.926	1.152	.909	.907	.887	.932	.876	.874
2	.883	.707	.923	.918	.828	.732	.835	.833
3+	1.051	1.213	.959	.957	1.081	1.518+	.969	.971

Table 8 *Results from the Cox regression models estimating the impact of the rye price on child mortality between the first and 15th birthdays.*

Model	1	2	3	4
N individuals (N death)	24,454 (3,352)	9,956 (1,064)	16,856 (2,376)	16,856 (2,376)
N observations	950,376	393,334	612,318	612,318
Log likelihood	-32,653.536	-9,379.3366	-22,055	-22,055.058
LR chi²	250.18	97.02	153.05	154.93
Prob > chi²	0.0000	0.0000	0.0000	0.0000
Hazard Ratios				
Rye price	1.001	1.076***	.991	.999
Interaction season*crop price				
Winter (ref.)	1	1	1	1
Spring	.993	.979	.999	.999
Summer	1.010	.965^{+}	1.024*	1.024*
Autumn	1.013	.987	1.022*	1.002^{+}
Social rank	N/A	N/A		
Large-scale farmer (ref.)			1	1
Mid-scale farmer			1.012	1.166
Small-scale farmer			1.062	1.092
Landless			1.095	1.234
Unknown			1.071	1.238
Interaction social rank*rye price	N/A	N/A	N/A	
Large-scale farmer (ref.)				1
Mid-scale farmer				.990
Small-scale farmer				.998
Landless				.991
Unknown				.989
Temperature Index	.931	1.114	.864**	.864**
Season				
Winter (ref.)	1	1	1	1
Spring	1.184	1.510^{+}	1.078	1.077
Summer	.807	1.473	.680*	.680*
Autumn	.792+	.980	.740	.740^{+}
Interaction season*temperature index				
Winter (ref.)	1	1	1	1
Spring	.974	.810^{+}	1.062	1.061
Summer	1.236**	1.239*	1.207*	1.207*
Autumn	1.240**	.959	1.367***	1.367+
Year	.992***	.985***	.990***	.990***
Sex (female)	.950+	.922	1.045 (t=.981^{+})	1.045 (t=.981*)
Birth rank	1.017	.979	1.026	1.025
Number of older brothers at birth				
0 (ref.)	1	1	1	1
1	1.093^{+}	1.111	1.087	1.078
2	1.073	1.232^{+}	1.026	1.016
3+	1.003	1.169	.986	.983
Number of older sisters at birth				
0 (ref.)	1	1	1	1
1	.963	1.046	.929	.929
2	.988	1.040	.954	.944
3+	.962	1.273^{+}	.880	.878

5.2.2 FERTILITY AND THE AGE AT FIRST MARRIAGE

In Table 9 we present the results from the Cox proportional regression models that estimate the female age at first marriage. Model 2 indicates that high rye prices delayed the female age at first marriage after 1820, whereas Model 3 indicates an accelerating effect for girls born to families established between 1720 and 1820 (HR=1.019*). However, this effect decreases with age (t=0.998**), and a model that does not control for the interaction with age/time shows no significant effect (results not shown). Model 4, which includes the same cases and covariates as Model 3, but also estimates the interaction between the price of rye and social rank, shows no significant effect of the rye price (HR=$0.996^{n.s.}$) or an interaction with age/time or an interaction with social rank. Model 3 indicates that the daughters of small-scale farming families, of landless families, and of families whose land ownership status is unknown were significantly older at their first marriage than the daughters of large-scale farming families (HRs=0.789***, 0.685***, 0.737***).

The results of the models that estimate the male age at first marriage are given in Table 10. Models 1 and 3 indicate that boys were younger at their first marriage when the rye prices were high, and that this effect decreased with age. Models that do not control for the interaction with time/age show no significant effects of the rye price (results not shown). Whereas girls from the lower social strata were older than average at their first marriage, Model 3 reveals the opposite pattern for boys. The sons of small-scale farming families, landless families, and families whose landownership status is unknown were significantly younger at their first marriage than the sons of large-scale farming families (HRs=1.335***, 1.481***, 1.351***).

The results of the multiple exit Cox regressions that estimate the effect of changes in the rye price on the fertility of married women are given in Table 11. Model 2, which does not include the period before 1820, shows that fertility was lower when the rye prices were high (HR=0.990*). In contrast, Model 3 indicates that among the families established between 1720 and 1810, fertility tended to be higher when the rye price was higher (HR=1.004^{+}). Model 4, which includes the same cases and covariates, and which estimates the interaction between the rye price and social rank, shows no significant effect of the rye price, although the value of the HR is similar (HR=$1.007^{n.s.}$). An effect for the interaction between social rank and the price of rye is not indicated.

The following is a brief summary of the most important results:

1. The large-scale farming families had more births and more children who survived to adulthood than the small-scale farming families, the landless families, or the families for whom the level of landownership was unknown. This pattern is attributable to the significantly shorter inter-birth intervals among the large-scale farming families, and not to lower infant mortality.

2. The male infants born to the landless families had lower mortality than those born to the large-scale farming families.

3. Changes in the price of rye had no effect on infant and child mortality before 1820. For the period after 1820 there is evidence that infant mortality was higher in winter, and that child mortality was generally higher when the rye price was high.

4. Warm summers and autumns were associated with increased infant and child mortality.

5. There is no or only weak evidence that the male or the female age at first marriage was affected by changes in the rye price.

6. The crop price affected the fertility of married women after 1820, but not in the study period before that year.

Table 9 *Results of the Cox regression models estimating the impact of the rye price on girls' age at first marriage.*

	Girls			
Model	1	2	3	4
N individuals (N marriages)	9,169 (6,764)	4,449 (3,390)	5,677 (4,113)	5,677 (4,113)
N observations	122,366	62,505	74,351	74,351
Log likelihood	-55,468.672	-25,369.368	-31,710.433	-31,715.498
LR chi²	110.46	121.69	167.27	157.13
Prob > chi²	0.0000	0.0000	0.0000	0.0000
Hazard Ratios				
Rye price	1.001	.979***	1.019* (t=0.998**)	.996
Period 1805-15	N/A	N/A	1.180**	1.186**
Social rank	N/A	N/A		
Large-scale farmer (ref.)			1	1
Mid-scale farmer			.902	.951
Small-scale farmer			.789***	.832
Landless			.685***	.637**
Unknown			.738***	.687*
Interaction social rank*rye price	N/A	N/A	N/A	
Large-scale farmer (ref.)				1
Mid-scale farmer				.996
Small-scale farmer				.996
Landless				1.005
Unknown				1.005
Birth cohort	.895*** (t=1.008***)	.894* (t=1.019***)	.918*** (t=1.007***)	.921*** (t=1.007***)
Birth rank	1.016*	1.024*	.928*** (t=1.006***)	.928*** (t=1.006***)
N of older sisters at birth				
0 (ref.)	1	1	1	1
1	.981	.969	.970	.971
2	.913+	.918	.952	.955
3+	.840*	.795*	.918	.920
N of older sisters at the age of 15				
0 (ref.)	1	1	1	1
1	1.013	1.122**	.887**	.886**
2	.992	1.114*	.858**	.858**
3+	1.010	1.148*	.853**	.853**

Table 10 *Results from the Cox regression models that estimate the impact of the rye price on the male age at first marriage.*

	Boys			
Model	1	2	3	4
N individuals (N marriages)	9,282 (6,434)	5,238 (3,906)	5,553 (3,752)	5,553 (3,752)
N observations	137,590	78,791	81,376	81,376
Log likelihood	-52,656.835	-29,836.724	-28,700.531	-28,703.155
LR chi²	60.85	87.57	109.86	104.61
Prob > chi²	0.0000	0.0000	0.0000	0.0000
Hazard Ratios				
Rye price	1.015* (t=.999*)	.999	1.018* (t=.998**)	.981+
Period 1805-15			1.148*	1.151*
Social rank	N/A	N/A		
Large-scale farmer (ref.)			1	1
Mid-scale farmer			1.081	.811
Small-scale farmer			1.335***	1.138
Landless			1.481***	1.137
Unknown			1.351***	1.101
Interaction social rank*rye price	N/A	N/A	N/A	
Large-scale farmer (ref.)				1
Mid-scale farmer				1.020
Small-scale farmer				1.011
Landless				1.019+
Unknown				1.013
Birth cohort	.919*** (t=1.006***)	.757*** (t=1.020***)	.929*** (t=1.005***)	.929*** (t=1.005***)
Birth rank	.998	1.001	.989	.989
N of older brothers at birth				
0 (ref.)	1	1	1	1
1	.999	1.010	1.009	1.008
2	.988	.992	1.025	1.026
3+	1.017	1.025	1.070	1.069
N of older brothers at the age of 15				
0 (ref.)	1	1	1	1
1	1.069*	1.143**	.996	.995
2	1.016	1.064	.961	.960
3+	.976	1.073	.885*	.883*

Table 11 *Results from the Cox regression models that estimate the impact of the rye price on the fertility of married women under age 45.*

Model	1	2	3	4
N mothers (N births)	4,137 (14,042)	1,395 (4,673)	2,857 (9.181)	2,857 (9,181)
N observations	52,484	17,342	33,903	33,903
Log likelihood	-103,642.86	-29,561.28	-63,702.917	-63,701.742
LR chi²	2418.22	742.57	1515.04	1517.39
Prob > chi²	0.0000	0.0000	0.0000	0.0000
Hazard Ratios				
Rye price	1.002	.990*	1.004⁺	1,007
Period 1805-15			.973	.973
Social rank	N/A	N/A		
Large-scale farmer (ref.)			1	1
Mid-scale farmer			.946	1.008
Small-scale farmer			.851**	.994
Landless			.777***	.795*
Unknown			.839***	.886
Interaction social rank*rye price	N/A	N/A	N/A	
Large-scale farmer (ref.)				1
Mid-scale farmer				.995
Small-scale farmer				.989
Landless				.998
Unknown				.996
Marriage cohort	.991**	.994	.999	1.000
Mother's age at first child birth	.439*** (t=1.019***)	.433*** (t=1.020***)	473*** (t=1.017***)	.473*** (t=1.017***)
Number of child births	.140*** (t=1.047***)	.138*** (t=1.047***)	.160*** (t=1.043***)	.160*** (t=1.043***)
Number of living daughters				
0	1.117***	1.093*	1.113***	1.113***
1 (ref.)	1	1	1	1
2	.932**	.941	.933*	.933*
3+	.951	.957	.947	.947
Number of living sons				
0	1.141***	1.134**	1.121***	1.121***
1 (ref.)	1	1	1	1
2	.945*	.983	.933*	.934*
3+	.930*	1.013	.896*	.896*

6 DISCUSSION

In this study we investigated how social status affected both reproduction and child survival in the historical population of the Krummhörn region. We analyzed the general long-term reproductive strategies of the different social strata (Set of Analyses I); as well as the short-term effects of changes in the rye price on infant and child mortality, the age at first marriage, and the fertility of married women (Set of Analyses II).

6.1 SET OF ANALYSES I – GENERAL DIFFERENCES BETWEEN THE SOCIAL STRATA

In the 18th century, the population of the Krummhörn region constituted a pre-industrial, agricultural society that was, like populations in other parts of Germany of that time period, not naturally fertile (Beise & Voland 2008). If we base the family size calculation exclusively on complete families, we find that the large-scale farming families had the highest number of births (5.074 ± 3.316), and that the families whose land ownership status is unknown had the lowest number of births (4.213 ± 2.783; see Table 1). Even the relatively high mean number of births observed among the large-scale farming families is not as high as would be predicted for a naturally fertile population. One reason for this rather low fertility was the relatively high age at first marriage. Girls were on average 26.285 ± 5.406 years old at their first marriage, and 99 percent of the women who married at least once gave birth to their last child before the age of 46.905. However, the majority of women stopped having children long before reaching that age. Among the women who survived their 45th birthday the average age at last childbirth was 37.988 ± 5.451 years (median age: 39.259 years). This means that a typical married woman of the Krummhörn region had a rather short fertile period. These findings, together with estimates that show that the inter-birth intervals were relatively long (2.623 ± 1.346 years), make it easy to understand why the average family had only four to five births. We argue that this practice of family limitation was a (functional) response to the limited expansion opportunities. This constraint was shared by families of all social strata. As we noted in the description of the study population, the Krummhörn region had been saturated since the late medieval period. Nevertheless, the reproductive strategies of families differed depending on their social stratum. As we had expected to find, and as was demonstrated using earlier versions of the Krummhörn database, which contained far fewer parishes and individuals (Klindworth & Voland 1995; Voland 1988, 1990; Voland & Dunbar 1995), the large- and the mid-scale farming families were able to convert their land ownership into reproductive success: they had both more births (Table 2) and more children surviving to adulthood (Table 3) because their inter-birth intervals were shorter (Table 4) than those of the small-scale farming families, the landless families, and the families for whom the landownership status was unknown. This finding is in line with those of other studies on both historical and contemporary populations that showed a positive correlation between the extent of landownership and reproductive success (Boone 1986; Borgerhoff Mulder 1987, 1988, 1990, 1995, 1996; Flinn 1986; Low 1991; Low & Clark 1992; Strassman 1997). Thus, our results on reproductive success match the predictions outlined in Hypothesis 1. However, our assumptions in Hypothesis 1 were not confirmed, as we found that overall infant and child mortality were not affected significantly by parental social status (Tables 4 and 5). The higher fertility of the large-scale and the mid-scale farming families resulted in more children surviving to adulthood. It might appear counterintuitive that parental social status did not affect infant mortality in a non-egalitarian economic society, but there are at least three possible explanations for why this was the case. First, as we mentioned above, the population of the Krummhörn region did not experience any periods of severe malnutrition or of famine during the study period. This was reflected in the finding that among all social strata infant and child mortality was low (Tables 4 and 5) in the region relative to other parts of Germany during the same time period (e.g., cf. Klüsener et al. 2014) for a systematic study for an earlier period). However, the infant mortality rate in the Krummhörn region was typical for rural Frisia. Van Poppel, Jonker and Mandemakers (2005) have estimated similar infant mortality rates for 19th-century West Frisia, which is located in the Netherlands. This suggests that enough food was available during the nursing period for women of all social strata. The power of this potential explanation will be picked up below, when we discuss the effects of short-term economic fluctuations. Second, in rural, pre-industrial societies in which there was no comprehensive medical care, mortality was highly associated with epidemics, which would have affected members of various social strata more or less equally (see e.g., D´Escheruy (1760) for smallpox). We tested whether life expectancy after age 15 was affected by social rank, and found no significant differences (results not shown). As has been shown elsewhere, a marked mortality differential between the social classes is a phenomenon of modern times, and the gap was less pronounced or non-existent before the start of industrialization, especially in the countryside (Woods 2003). This finding also supports the hypothesis that while the various strata experienced different social conditions, they had the same mortality regime (Bengtsson & Dribe 2011). Third, it might have been the case that the better living conditions that the infants of the large-scale and the mid-scale farming families presumably experienced were offset by opposing effects. For example, the children of the large-scale and the mid-scale farming families may have benefited from good living conditions related to the social status of their parents, but they may also have been negatively affected by the significantly smaller inter-birth intervals, which can increase infant mortality (Alam 1995).

From a behavioral ecological perspective, the reproductive value (Fisher 1930) of a child is mainly based on the child's anticipated ability to successfully reproduce in the future. The child who was considered most likely to reproduce would therefore have received more parental care and support than his or her siblings. In addition, children may have had a certain value for their parents if their labor or material contributions (wages) could substantially increase their parents' reproductive success. Parents therefore might have—either temporarily or continuously—exploited one or more of the older offspring, making them so-called "helpers at the nest" (Crognier et al. 2001). The intensity of the exploitation might have ranged from a short time span during which the (grown-up) child was forced to delay marriage in order to support the natal family, up to a permanent suppression of the child's own reproduction (Voland 1998). These scenarios might be interpreted as a special case of parent-offspring conflict (Trivers 1974). Whether and how adult children were forced by their parents to act as "helpers at the nest," and how the parents manipulated their children's reproduction was dependent, along with other factors, on two main traits: the sex of the offspring and the number of surviving older siblings. From a naïve evolutionary perspective, we may assume that the families of higher social rank would have invested more in their male than in their female offspring (Trivers & Willard 1973). Against this theoretical background, it appears counterintuitive that the large-scale farming families had fewer boys (Table 1), and that these boys had higher infant mortality rates than the boys born to the landless families (Table 4). Nevertheless, we argue that this finding is in line with an evolutionary perspective on human reproductive behavior. The higher mortality among the boys born to families of high social rank was caused by a reproductive constraint imposed by the inheritance system of the Krummhörn region, which substantially decreased the reproductive value of sons among the elite. Given the system of ultimogeniture and the requirement that the other siblings are compensated, large-scale farming families risked social decline in the next generation if they produced too many adult male offspring. Voland and Dunbar (1995), using an earlier version of the Krummhörn database, showed that among the elite, a male infant's mortality risk increased significantly based on the number of living older brothers he had at birth. In other words, the number of living older sons was related to the intensity with which the parents cared for their newborn son.

The concepts of an offspring's reproductive value and an offspring's potential use as a "helper at the nest" can also be used to explain why the girls born to a family of a lower social rank or for whom the level of land ownership was unknown were significantly older at their first marriage (Table 9, see Model 3). In most agricultural societies, older daughters were more likely to be charged with the task of caring for their younger siblings, whereas boys were generally assigned physical tasks like fieldwork, which take place outside of the household. For the families who were not wealthy enough to employ a children's nurse, the firstborn daughters were enormously helpful in performing household tasks and in caring for their younger siblings. The situation was quite different when the family had property and employees who worked in the household. Among the large-scale farming families, the labor of daughters was less needed in the household, which may be one of the reasons why these girls were allowed to leave the family earlier than the daughters of the lower social strata. This interpretation is consistent with the findings of a study by Beise and Voland (2008), which showed that in landless families in the Krummhörn region there was enhanced competition between sisters to get married. In addition, we investigated whether the daughters of the landless families were more likely to marry up (results not shown). The fraction of the daughters of the landless families who married a landowning man (5.4%; N=62) was equal to the fraction of the landless sons who married a landowning woman (N=57). Hence, we did not find evidence for a general trend of landless daughters marrying up. This in turn suggests that it was unlikely that the daughters of the landless families were able to trade their reproductive merits for upward social mobility.

In summary, the members of the various social strata pursued different strategies, which can in turn be interpreted as a response to the different constraints that prevailed in the respective social strata. The elite were able to produce more offspring than the lower social strata as a result of their shorter inter-birth intervals, even though there was economic pressure to have a smaller number of sons. The landless families delayed the marriages of their daughters, most likely so that they could retain their daughters for a certain period of time as helpers in the household.

6.2 SET OF ANALYSES II - SHORT-TERM MORTALITY AND THE FERTILITY RESPONSES OF THE SOCIAL STRATA TO CHANGES IN THE PRICE OF RYE

6.2.1 INFANT AND CHILD MORTALITY

In contrast to our expectations, we have found no evidence that changes in the rye price affected the social strata differently. Obviously, the infants and children of the different social strata faced the same mortality regime in the study period. Our failure to find a relationship between the rye price and mortality or fertility is inconsistent with the results of other studies on historical populations, which showed that the crop price had a clear impact on mortality (Fogel 1986) and fertility, especially among landless and poor families for a historical population in southern Sweden (Bengtsson & Dribe 2006), and for an urban population in pre-revolutionary France (Galloway 1986). However, this finding is in line with the results of a study on a historical Finnish dataset, which also found that the associations between crop yields and mortality or fecundity were generally weak (Hayward et al. 2012). Moreover, a study by Amialchuk and Dimitrova (2012), who analyzed deliberate birth spacing among 14 German parishes from the 18th and 19th centuries, reached a similar conclusion. They found that crop prices did not significantly affect birth spacing before 1800 in the studied population. As we explained above, our study period largely coincides with that of Amialchuck and Dimitrová. The 19th century in Germany was characterized not only by industrialization, but also by a substantial change in the working relationship between large-scale farmers and landless agricultural workers; even the regions that industrialized slowly, like the Krummhörn, were affected. Before 1820 *Tischgemeinschaften* (table fellowships) were common (Arends 1818-1820). The large-scale farmers felt responsible for their workers, and shared a table with them. In the first half of the 19th century this social arrangement disappeared, and was replaced by a capitalist hire-and-fire mentality. Therefore, changes in that crop prices that might have affected the living costs of the landless workers may have been buffered by the rich employers. It is reasonable to assume that the large-scale farmers offered their employees subsidized food or credit with favorable conditions. This assumption also explains why child mortality increased overall after 1820 (see Model 2, Table 8). Thus, we conclude that the table fellowship society of the 18th century played an important role in mortality. Furthermore, we are not surprised to find that in contrast to child mortality, infant mortality after 1820 was affected only during winter. There is evidence that mothers in the Krummhörn region breastfed their children (Willführ & Gagnon 2013). If a maternal organism is able to successfully give birth to a child, it is likely that the family has sufficient resources to feed the mother, which may in turn shield the infant from nutritional fluctuations. After weaning, however, even short periods of malnutrition might be linked to higher mortality, because the child's resistance to pathogens might be reduced (Kloke 1998).

Another potential explanation for the association between child mortality and the rye price after 1820 (which does not exclude the explanation above) is that the (market) rye prices before 1820 did not accurately reflect the cost of living. This is particularly likely to have been the case during the era of Napoleonic influence in Europe (until the Congress of Vienna in 1815), in which the crop price was more affected by political issues rather than by crop production. The Continental System (1806-1814) had a substantial impact on the economy of East Frisia, as the region was highly dependent on trade with England (Grab 2003). When trade with England was no longer possible, the crop prices crashed and large numbers of people were unemployed. After 1815, East Frisia, and thus the Krummhörn region, belonged to the Kingdom of Hanover. The period of 1815 to 1859 was characterized by relatively stable economic conditions.

Another finding of our study is that infant and child mortality was higher during warm summers. We believe that this was modulated by diseases. The Krummhörn was a coastal region with a relatively warm and humid climate. Since under these conditions disease-causing bacteria are viable outside of the human body and viruses are infectious for longer, the infection rates were higher during these periods. Although it was not possible to identify the most common type of disease, we know that the Krummhörn region had high levels of malaria during the study period (Dalitz 2005; Harcken-Junior 2004). The developmental cycle of the Anopheles mosquito shortens significantly in warm summers, and this mosquito has been found to have caused epidemics in the southern coastal region of the

North Sea (Martini 1952). In some summers, such as in the summer of 1826, every second child reportedly showed symptoms of malaria (Martini 1937).

6.2.2 FERTILITY AND THE AGE AT FIRST MARRIAGE

The results of the models that estimate the impact of changes in the rye price on the fertility of married women and on the age at first marriage are largely in line with the results of our mortality analyses (Tables 9, 10 and 11). Again, the effects appear to have been different before and after 1820. For the period for which we were able to estimate the families' social rank (mainly during the 18th century), we find no significant effects on the age at first marriage or on fertility. As reported in the Set of Analyses I, there are general differences between families of different social strata, but we found no interaction between changes in the rye price and social rank, which indicates that the different social strata had not been affected differently. However, after 1820 the situation changed, as high rye prices were associated with lower fertility among married women, and the average age at first marriage for both males and females was affected. Unfortunately, because of the missing tax roll information for the 19th century, we were not able to investigate whether there were social stratum-specific responses to changes in the rye price, beyond measuring the general impact. We can speculate whether the rich families might have faced different conditions than the families who were less prosperous, but until we are able to estimate the socioeconomic backgrounds of families, we cannot answer this question.

Another explanation for the inconsistency in the effects of price on mortality and fertility is that the market crop prices might be an insufficient proxy for families' actual costs of living. Although this statement is more or less speculative, it also explains why the removal of the price trend has no effect on our results (see section 3.2). Many factors might play a role here. One potential factor, the *Tischgemeinschaft*, was mentioned above. It should also be noted that the crop prices used in this study are taken from larger trade markets in the cities of Emden and Norden, and we cannot tell how closely these prices were linked to local bread prices. Another problem, which has also been addressed by Oberschelp (1986), is that the relationship between wages and crop prices is highly dynamic and complicated. For the reasons stated above, we believe that the results of analyses of price effects should be interpreted with caution.

6.3 CONCLUDING REMARKS

In sum, we interpret our results as providing support for the assumption that members of different social strata pursued different long-term reproductive strategies, but did not respond very differently to short-term economic fluctuations, at least until the beginning of the 19th century. We believe that this finding is explained in large part by the widespread practice of table fellowships, which were an important feature of the socioeconomic environment in the 18th century. There were, of course, different permanent constraints within the various social strata which generated different stratum-specific reproductive behaviors, but there is no evidence that members of the various social strata faced different mortality regimes. However, the situation changed around the beginning of the 19th century. The transition to a capitalist society in which the elite no longer felt responsible for the welfare of their employees might have led to stratum-specific mortality differentials in the later part of the 19th century. But because we are unable to classify marriages by social rank after 1810 we cannot tell whether and how the different social strata were affected. We have shown that child mortality was significantly affected by the crop price after 1820. It is reasonable to argue that the majority of the children who died from malnutrition belonged to the lower social classes. But although this increase in mortality was significant, the effect size was rather small because child mortality was low in the entire study relative to that of other regions during the same time period. Furthermore, clear stratum-specific mortality differentials among children and adults are mainly found in urban environments. Since the Krummhörn region has historically been a rural habitat, and remains rural up to today, the mortality differences might have been minor in any case.

ACKNOWLEDGEMENTS

We would like to thank Eckart Voland for access to the Krummhörn database and for his generous support which substantially contributed to the quality of this paper. Further we would like to thank Luciana Quaranta from Lund University for methodological inspiration and Jonathan F. Fox from the Freie Universität Berlin for feedback on an earlier version of this paper.

REFERENCES

Alam, N. (1995). Birth spacing and infant and early childhood mortality in a high fertility area of Bangladesh: age dependent and interactive effects. *Journal of Biosocial Science*, 27(04), 393-404.
DOI: http://dx.doi.org/10.1017/S0021932000023002

Amialchuk, A. & Dimitrova, E. (2012). Detecting the evolution of deliberate fertility control before demographic transition in Germany. *Demographic Research*, 27(19), 507-542.
DOI: 10.4054/DemRes.2012.27.19

Arends, F. (1818-1820). *Ostfriesland und Jever in geographischer, statistischer und besonders landwirthschaftlicher Hinsicht.* Emden.

Arslan. (in prep). Paternal age at conception predicts lower offspring fitness in humans. Manuscript in preparation.

Beise, J. (2001). *Verhaltensökologie menschlichen Abwanderungsverhaltens - am Beispiel der historischen Bevölkerung der Krummhörn (Ostfriesland, 18. und 19. Jahrhundert).* Doctoral thesis, University of Giessen.

Beise, J. & Voland, E. (2008). Intrafamilial resource competition and mate competition shaped social-group-specific natal dispersal in the 18th and 19th century Krummhörn population. *American Journal of Human Biology*, 20(3), 325-336.
DOI: 10.1002/ajhb.20730

Bengtsson, T. & 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., Campbell, C. & Lee, J. Z. (Eds.). (2004). *Life under pressure.* Cambridge, MA: MIT Press.

Bengtsson, T. & Dribe, M. (2011). The late emergence of socioeconomic mortality differentials: A micro-level study of adult mortality in southern Sweden 1815–1968. *Explorations in Economic History*, 48(3), 389-400.
DOI: http://dx.doi.org/10.1016/j.eeh.2011.05.005

Boone, J.L. (1986). Parental investment and elite family structure in preindustrial states: A case study of late medieval-early modern Portuguese geneologies. *American Anthropologist*, 88(4), 859-878.
DOI: 10.1525/aa.1986.88.4.02a00050

Borgerhoff Mulder, M. (1987). Cultural and reproductive success: Kipsigis evidence. *American Anthropologist*, 89(3), 617-634.
DOI: http://www.jstor.org/stable/678055

Borgerhoff Mulder, M. (1988). Reproductive success in three Kipsigis cohorts. In: T.H. Clutton-Brock (Ed.), Reproductive success: *Studies of individual variation in contrasting breeding systems* (pp. 419-435). Chicago: University of Chicago Press.

Borgerhoff Mulder, M. (1990). Kipsigis women's preferences for wealthy men: Evidence for female choice in mammals? *Behavioral Ecology and Sociobiology*, 27(4), 255-264.
DOI: 10.1007/BF00164897

Borgerhoff Mulder, M. (1995). Bridewealth and its correlates. Quantifying changes over time. *Current Anthropology*, 36(4), 573-603.
DOI: http://www.jstor.org/stable/2744247

Borgerhoff Mulder, M. (1996). *Responses to environmental novelty: Changes in men's marriage strategies in a rural Kenyan community. Proceedings of the British Academy*, 88, 203-222

Borgerhoff Mulder, M., Bowles, S., Hertz, T., Bell, A., Beise, J., Clark, G., . . . Wiessner, P. (2009). Intergenerational wealth transmission and the dynamics of inequality in small-scale societies. *Science*, 326(5953), 682-688.
DOI: 10.1126/science.1178336

Cox, D.R. (1972). Regression models and life-tables. *Journal of the Royal Statistical Society, Series B (Methodological)*, 34(2), 187-220.Crognier, E., Baali, A. & Hilali, M.K. (2001). Do "helpers at the nest" increase their parents' reproductive success? *American Journal of Human Biology*, 13(3), 365-373.
DOI: http://www.jstor.org/stable/2985181

Crognier, E , Baali, A, & Hilali, MK (2001). Do "helpers at the nest" increase their parents' reproductive success? *American Journal of Human Biology*, 13(3), 365-373.
DOI: 10.1002/ajhb.1060

Cronk, L. (1991). Human behavioral ecology. *Annual Review of Anthropology*, 20, 25-53.
DOI: http://www.jstor.org/stable/2155792
D´Escheruy, D. (1760). An essay on the smallpox.
Dalitz, MK. (2005). *Autochthone Malaria im mitteldeutschen Raum*. Martin-Luther-Universität, Halle-Wittenberg.
Dribe, M., Oris, M. & Pozzi, L. (2014). Socioeconomic status and fertility before, during, and after the demographic transition: An introduction. *Demographic Research*, 31(7), 161-182.
DOI: 10.4054/DemRes.2014.31.7
Fisher, R.A. (1930). *The genetical theory of natural selection*. Oxford: The Clarendon Press.
Flinn, M. (1986). Correlates of reproductive success in a Caribbean village. *Human Ecology*, 14(2), 225-243.
Fogel, R.W. (1986). Nutrition and the decline in mortality since 1700: some additional preliminary findings (Working Paper No. 1802).
Galloway, P.R. (1986). Differentials in demographic responses to annual price variations in pre-revolutionary France: A comparison of rich and poor areas in Rouen, 1681 to 1787. *European Journal of Population*, 2(3), 269-305.
DOI: 10.1007/BF01796594
Galloway, P.R. (1988). Basic patterns in annual variations in fertility, nuptiality, mortality, and prices in pre-industrial Europe. *Population Studies*, 42(2), 275-303.
DOI: 10.1080/0032472031000143366
Glaser, R. & Riemann, D. (2010). Central Europe 1000 Year Documentary Temperature Reconstruction. In: IGBP PAGES/World Data Center for Paleoclimatology Data Contribution (Ed.). Boulder CO, USA: NOAA/NCDC Paleoclimatology Program.
Grab, A. (2003). *Napoleon and the transformation of Europe*. New York: Palgrave Macmillan.
Harcken-Junior, W. (2004). *Marschenfieber. Ein medizin-historischer Beitrag zur Kulturgeschichte der Marschen der südlichen Nordsee.* Oldenburg: Isensee.
Hayward, A.D., Holopainen, J., Pettay, J.E. & Lummaa, V. (2012). Food and fitness: Associations between crop yields and life-history traits in a longitudinally monitored pre-industrial human population. *Proceedings of the Royal Society of London B: Biological Sciences*, 279(1745), 4165-4173.
DOI: 10.1098/rspb.2012.1190
Klindworth, H. & Voland, E. (1995). How did the Krummhörn elite males achieve above-average reproductive success? *Human Nature*, 6(3), 221-240.
DOI: 10.1007/BF02734140
Kloke, I. E. (1998). *Säuglingssterblichkeit in Deutschland im 18.und 19. Jahrhundert am Beispiel von sechs ländlichen Regionen* (Doctoral dissertation). Retrieved from Freie Universität Berlin, Berlin.
Klüsener, S., Devos, I., Ekamper, P., Gregory, I., Gruber, S., Martí-Henneberg, J., . . . Solli, A. (2014). Spatial inequalities in infant survival at an early stage of the longevity revolution: A pan-European view across 5000+ regions and localities in 1910. *Demographic Research*, 30(68), 1849-1864.
DOI: 10.4054/DemRes.2014.30.68
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.
Lin, D.Y. (1994). Cox regression analysis of multivariate failure time data: The marginal approach. *Statistics in Medicine*, 13, 2233-2247.
Low, B.S. (1991). Occupational status, land ownership, and reproductive behavior in 19th century Sweden: Tuna Parish. *American Anthropologist*, 92, 115-126.
DOI: 10.1525/aa.1990.92.2.02a00130
Low, B.S. & Clark, A.L. (1992). Resources and the life course: Patterns through the demographic transition. *Ethology and Sociobiology*, 13(5-6), 463-494.
DOI:10.1016/0162-3095(92)90013-T
Martini, E. (1937). Über die Malaria-Epidemie an der Nordseeküste 1826. *Zeitschrift für Hygiene und Infektionskrankheiten*, 120(1), 36-43.
DOI: 10.1007/BF02177772
Martini, E. (1952). *Lehrbuch der medizinischen entomologie* (4th ed.). Jena: Gustav Fischer Verlag.
Myrskylä, M. & Fenelon, A. (2012). Maternal age and offspring adult health: evidence from the health and retirement study. *Demography*, 49(4), 1231-1257.
DOI: 10.1007/s13524-012-0132-x

Oberschelp, R. (1986). Beiträge zur niedersächsischen Preisgeschichte des 16. bis 19. Jahrhunderts. Hannover: Verlag August Lax Hildesheim.

Ohling, J. (1963). *Die Acht und ihre sieben Siele. Kulturelle, wasser- und landwirtschaftliche Entwick lung einer ostfriesischen Küstenlandschaft.* Pewsum: Eigenverlag.

Pawłowski, B. (2000). The biological meaning of preferences on the human mate market. *Anthropological Review*, 63, 39-72.

Pettay, J.E., Helle, S., Jokela, J. & Lummaa, V. (2007). Wealth class-specific natural selection on female life-history traits in historical human populations. *PLOS One*, 2(7), e606. DOI: 10.1371/journal.pone.0000606

Quaranta, L. (2013). *Scarred for Life. How conditions in early life affect socioeconomic status, reproduction and mortality in Southern Sweden, 1813-1968* (Doctoral dissertation). Lund University.

Rutstein, S.O. (1984). *Infant and child mortality: levels, trends and demographic differentials. Revised edition.* Voorburg, the Netherlands: International Statistical Institute.

Skirbekk, V. (2008). Fertility trends by social status. *Demographic Research*, 18(5), 145-180.

Störmer, C. (2011). Sex differences in the consequences of early-life exposure to epidemiological stress - a life-history approach. *American Journal of Human Biology*, 23(2), 201-208.

Strassman, B. (1997). Polygyny is a risk factor for child mortality among the Dogon. *Current Anthropology*, 38(4), 688-695.

Trivers, R.L. (1974). Parent-offspring conflict. *American Zoologist*, 14(1), 249-264.

Trivers, R.L. & Willard, D.E. (1973). Natural selection of parental ability to vary the sex ratio of offspring. *Science*, 179(4068), 90-92.

Van Poppel, F., Jonker, M. & Mandemakers, K. (2005). Differential infant and child mortality in three Dutch regions, 1812–1909. *The Economic History Review*, 58(2), 272-309.

Voland, E. (1988). Differential infant and child mortality in evolutionary perspective: Data from the late 17th to 19th century Ostfriesland (Germany). In: L. Betzig (Ed.), *Human reproductive behavior* (pp. 253 - 276). Cambridge: Cambridge University Press.

Voland, E. (1990). Differential reproductive success within the Krummhörn population (Germany, 18th and 19th centuries). *Behavioral Ecology and Sociobiology*, 26(1), 65-72. DOI: 10.1007/BF00174026

Voland, E. (1995). Reproductive decisions viewed from an evolutionary informed historical demography. In: R.I.M. Dunbar (Ed.), *Human Reproductive Decisions - Biological and Social Perspectives* (pp. 137-159). London: Palgrave MacMillan.

Voland, E. (1998). Evolutionary ecology of human reproduction. *Annual Review of Anthropology*, 27, 347-374. DOI: http://www.jstor.org/stable/223375

Voland, E. (2000). Contributions of family reconstitution studies to evolutionary reproductive ecology. *Evolutionary Anthropology*, 9(3), 134-146. DOI: 10.1002/1520-6505(2000)9:33.0.CO;2-M

Voland, E. & Dunbar, R.I.M. (1995). Resource competition and reproduction: The relationship between economic and parental strategies in the Krummhörn population (1720–1874). *Human Nature*, 6(1), 33-49. DOI: 10.1007/BF02734134

Willführ, K.P. & Gagnon, A. (2013). Are step-parents always evil? Parental death, remarriage, and child survival in demographically saturated Krummhörn (1720-1859) and expanding Québec (1670-1750). *Biodemography and Social Biology*, 59(2), 191-211. DOI: 10.1080/19485565.2013.833803

Woods, R. (2003). Urban-rural mortality differentials: An unresolved debate. *Population and Developmental Review*, 29(1), 29-46. DOI: 10.1111/j.1728-4457.2003.00029.x

Wrigley, E.A. & Schofield, R.S. (Eds.). (1989). *The population history of England, 1541-1871*. A reconstruction. London: Edward Arnold.

Zhu, J.L., Vestergaard, M., Madsen, K.M. & Olsen, J. (2008). Paternal age and mortality in children. *European Journal of Epidemiology*, 23(7), 443-447. DOI: 10.1007/s10654-008-9253-3