Title: With or without the help of kin? - Cooperative breeding between natal support, in-law opportunities, and consanguinity

Author: Kai P. Willführ (Carl von Ossietzky University, Oldenburg, Germany)
email: kai.willfuehr@uol.de

Abstract

This study investigates the impact of kinship on fertility in the historical population of the Krummhörn region in Germany [1720 – 1875]. Poisson regression analysis is used to investigate the effect of time shared between 4,807 reproductive females and their biological parents as well as parents-in-law on the absolute number of births and surviving children. Models with a minimum set of control variables suggest that biological parents and the mother-in-law are associated with higher fertility. However, this association is not suggested, if the models control for the time period women are married before the age of 45. In a more sophisticated approach, multiple-failure Cox regression analysis is used to model the effect of kin on inter-birth intervals. This approach relies on a combination of models adjusted by clustering at the family level, and models stratified at the family level. Beside the parents and parents-in-law, time-varying information about the availability of siblings and siblings-in-law are included in the models. The results of the Cox regression analysis suggest that fertility of married females was not affected by kinship or by kin present in the same parish of residence. This study is line with other studies using historical data from Europe which also suggest that kin availability was not a significant factor for fertility. It is argued that kinship might have been more important regarding marriage formation in demographic saturated population, whereas kin might directly promote fertility in demographically expanding populations.

Motivation

There is an ongoing debate in social science how kin affect human fertility. Family forms and typical kin compositions vary through time and place and the impact of kin relationships on fertility may be complex and context-specific (Sear 2018). Evolutionary anthropologists have hypothesized that humans are cooperative breeders which includes supportive as well as competitive kin behavior. In the present study I add another tessera to this mosaic by investigating parity and interbirth intervals of the historical population of the Krummhörn region in Northwest Germany (1720 – 1874). The Krummhörn region is an interesting study object for the investigation of kin effect on human fertility for multiple reasons. Beside the good data quality, which allows life course reconstruction including reconstruction of the residence on the level of parishes and the long study period, the people of the demographically saturated Krummhörn region were confronted with a displacement competition which is also sometimes called (high)-K selection (Figueredo et al. 2006). In such a scenario reproductive success is not necessarily achieved by large family sizes, but by social positioning and other forms of offspring per-capita investment. A distinct social stratification which was maintained via inheritance of farmland caused increased inbreeding especially among wealthy families who practiced consanguineous marriage in order to concentrate wealth though the patriline (Johow, Willführ, Voland 2019). A previous study on the effect of kin network composition on the mortality of reproductive females using the same study population (Willführ, Johow, Voland 2018) suggested that mortality of reproductive females was reduced by the presence of the mother-in-law but increased by biological sisters. The positive mother-in-law effect was particularly strong among the economic elite. The question which arises is whether these kin effects on mortality of reproductive females are also crucial for their fertility.

Data

I utilize the archive ZA8630: Familienrekonstitution der Krummhörn (Ostfriesland), 1720-1874[1]. The files provide individual vital data, information on genealogical relationships, as well as other forms of information, such as geographic data, land ownership, and occupations, for 34,708 reconstituted families who lived in the Krummhörn (Ostfriesland) in the 18th and 19th centuries. Parish records from a total of 33 parishes in the Krummhörn and various tax lists are our primary data sources. An overview of the methodology of this family reconstitution can be found in Voland (2000) and Willführ et al. (forthcoming). Currently, there are 65 scientific publications based on this on this database[2].

Within the study period the population can be described as a typical early capitalistic agricultural society which was characterized by significant social stratification. Many of the records dated before 1720 are incomplete, and families from the social and economic elite tend to be overrepresented in these early records. After 1874, the church was no longer responsible for maintaining records of births, deaths, and marriages, as this task had been transferred to the civil registry offices ("Standesämter"). Due to the bias in the early records and the censoring after 1874, the analysis is limited to females who survived childhood and who were born to marriages which had been contracted between 1720 and 1850 (N= 10,162).

Geographically, the peripheral rural region of the Krummhörn is bordered to the north and west by the North Sea; to the south by the River Ems; and to the east by sandy soil and moorlands, which were impenetrable at that time. The Krummhörn region itself had very fertile marsh soil that was suitable for raising both crops and livestock. In the late medieval period, the settlement of the Krummhörn region had been completed (Ohling, 1963), and there was no significant population growth during the study period (Klöpper, 1949). As the region was a saturated habitat with a finite amount of arable land, the population faced local resource competition (Voland and Dunbar, 1995) and a stratified social structure arose among the Krummhörn population. The large-scale farmers with capital and status were at the top of this social hierarchy, while the small-scale farmers, craftsmen, and landless

[1] Preserved under http://dx.doi.org/10.4232/1.12643 for this study

[2] A list of publications derived from this project can be found (Voland) https://eckart-voland.de/pdf/KH-LIT.pdf.

workers occupied the lower end of this social structure. In the 18th century about 70 percent of the Krummhörn's families had either no land at all or their farms were too small to ensure subsistence, and thus were forced to supplement their income by working for the large-scale farmers (Willführ and Störmer, 2015; Knottnerus, 2004). Although there are no records indicating that the region was affected by famine or war during the study period, as in other parts of Europe, smallpox and other infectious diseases took a significant toll on the people of the region over the course of the 18th century (Omran, 2005). The average family size was about four children (Voland and Dunbar, 1995; Willführ and Störmer, 2015). The families of the region practiced a form of ultimogeniture in which the youngest son inherited the undivided farm from the father and the other offspring had to be compensated, often with cash (Ohling, 1963). A daughter could expect to receive half of the amount of compensation each son received. Due to these inheritance practices families in the Krummhörn region tended to be relatively small, and the average age at first marriage was high (female average age at first marriage: 26.285 (± 5.406) – Willführ and Störmer, 2015). Thus, late reproduction and low birth rates were the norm.

Methods

Poisson regression analysis

I use Poisson regression models to investigate the effect of shared time between reproductive females and their biological as well as between their parents-in-law on the number of births and the number of children surviving to age 15, respectively. These analyses are based on complete families where both, husband and wife survived wife's 45th birthday. This selection criterium is important since the death of one of the spouses before wife's menopause might disguise possible effects of relatives on fertility patterns. Shared time between wife and her kin are included as continuous variables in the models and represent the years shared between wife's (first) marriage until her 45th birthday. Cases where the death date of a parent is unknown or were the parent died before wife's first marriage are coded as zeros in order to include these cases in the model (NAs would be removed).

I use several models to investigate the association between shared time of reproductive females and their parents. In a first step, I estimate the effect of each parent separately in models with wife's birth cohort and birth rank as controls. In the next step, I estimate the effect of shared time between wife and her biological and in-law parents in the same model. In final step, I include also wife age [in years] at first as well as at last childbirth in the model. The results of the Poisson regression analysis are given in Table 1 in the result section.

Multiple-failure Cox regression analysis

Poisson regression analysis provides a good overview of fertility outcomes, but this method has limitations when age-effects of the focal individual or time-varying effects of the independent variables are considered. In order to meet these requirements, I apply multiple failure Cox survival regression to model the length of intervals between wife's childbirths. In estimating the kin effects on the inter-birth-intervals, I rely on a combination of models adjusted by clustering at the family level, and models stratified at the family level (family fixed effects) (Allison 2009). The former models investigate the general association between having kin and mortality among reproductive females, and thereby estimate the net result of kin effects. The latter models estimate likelihood functions with separate terms for each of the families in the dataset, and thus allow each family to have their own individual baseline hazard function. The key difference between the stratified and the clustered Cox regression models is that the stratified models identify kinship effects using the variation within families, but not between families. These stratified models control for unobserved heterogeneity if these factors are shared by reproductive sisters. By comparing the results of the clustered with the results of the stratified models I try to disentangle kin effects which were attributable to common causes from those which were directly linked to family members' behavior or accompanying factors. For example, genetic behavioral studies suggest that fertility patterns such as age at first childbirth and total parity are to a large degree heritable and therefore shared between relatives who are genetically closely related (Tropf et al. 2015; Barban et al. 2016). But also shared household and other family characteristics might disguise or moderate the effects which derive from direct interactions between kin. However, one disadvantage of the fixed-effect approach is that the models exclude singlets (in our case females without any reproductive sister in the dataset) from the analysis. Dependent on the structure of the data, the number of cases is therefore often substantially smaller in the fixed-effect version when compared to the clustered model version. Thus, if there are inconsistent findings in both model versions, it must be tested whether this is due to the exclusion of cases or due to the different estimation of the likelihood function. This could be shown by re-running the cluster model versions with exact the same number of cases which are included in the fixed-effect approach.

As a behavioral ecologist I am mainly interest in kin effects which can be defined as supportive or competitive behaviour in social interactions between relatives (Willführ et al., in press). However, the presence of kin may also be related to differential fertility among their relatives due to non-behavioral characteristics of the kin network, such as socioeconomic status. These kin correlations may disguise behavioral kin effects and did not receive appropriate attention in many previous studies. I try to disentangle kin correlations from behavioral kin effects based on the assumption that the latter require a certain level of spatial proximity. The time-varying information on the availability of the parent's and the parents-in-law, is included as categorical variables in the model. The reference category are episodes where the respective parent was living outside the parish, but within the Krummhörn region. Episodes where the parent was present in the same parish and where he or she was deceased, are then compared to the reference category. For cases in which parent's date of death is missing, I put episodes after the last date of observation (e.g. after last known childbirth in the study area) in a separate category indicating censorship in order to keep these episodes in the model. Kin which can come in multiple numbers, for instance brothers and sisters, the categories represent more complex information. I choose episodes in which siblings where exclusive living outside the parish as reference category, because usually adult individuals had siblings in the study area. This reference is then compared to episodes in which sisters or brothers were present in the same parish as well as to episodes in which there were no sisters or brothers living in the study area.

Each change in the kin composition (birth or death of an individual family member) is an event which brings a new episode of observation to the model. These linkages result in a large data setup; on average, there are more than 21 events for each woman between the date of her first marriage and the date of her exit from the sample (upon surviving to age 45 or prior death). The impact of kin on the length of the interbirth intervals is estimated only during a woman's first marriage. Episodes after the husband's death are excluded from the analysis, as it is unclear how the relationship between the reproductive woman and her in-law kin would have been affected by her husband's death or by her remarriage.

For all the different models estimated, we include a set of covariates that control for potential confounding conditions based on the context into which a woman was born and was living. The primary variables of interest are those for kinship formation. The rest of the covariates are included because they may be correlated with both the dependent outcome and kin formation. The lengths of interbirth intervals might be affected by reproductive characteristics such as the number of sons and daughters alive as well as ever born. Another important factor is the survival status of the lastborn child, since the parent might produce a (replacement) child sooner when compared the case were the lastborn child had survived. I also include a set of individual controls. I include the socio-economic status of the current marriage in the models since Willführ and Störmer (2015) showed that the interbirth intervals were shorter among the socio-economic elite. The models further include wife's birth cohort, which is coded in decades, to control for changes in the population over time, and for the individual's birth rank (Rutstein 1984). To avoid the risk of model overspecification, I create model sets which range from the raw model over models which include only reproductive and/individual control to the full model which includes all controls.

All analyses were performed in R version 3.5.3 using the packages data.table, reshape, and Hmisc (includes survival).

Data Selection

From the 10,162 females that were born to marriages contracted between 1720 and 1850 1,629 are excluded because their parents' marriage was not entirely under observation. Another 2,230 women are excluded, because they married more than once, and the order of their marriages is not reconstructable due to missing date of marriage. From this remaining sample of 6,303 women 1,367 more are excluded, because they did not produce children within the study area. As aforementioned, I do not include episodes after 31th December 1874 in my analyses, which results in the exclusion of another 129 women from the sample who gave birth to their first child after 1874. My final sample contains 4,807 women who derived from 3,293 families and who gave birth to 14,873 children in their first marriage (3.09 children per women).

Results

Poisson regression analysis

The models which do not include wife's ages at first and last childbirth suggest that the number of children born as well as the number of children who survived until adulthood is statistically significantly increased by the time the focal individual shares with her biological parents as well as with her mother-in-law (Table 1). However, the models which include age at first and last childbirth do not suggest that there is an association between the number of children born and surviving, respectively, and time shared between the wife and her biological and in-law parents.

Table 1 - Results of the Poisson regression analysis

	Number of children born				Number of children surviving to adulthood			
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 1**	**Model 2**	**Model 3**	**Model 4**
(Intercept)	5.182*** (.738)	3.453*** (.918)	3.530*** (.924)	3.537*** (.923)	1.069 (0.864)	-.405 (1.068)	-.352 (1.074)	3.537*** (.923)
Shared time with mother-in-law	.003* (.001)		.001 (.001)	.001 (.001)	.003* (.001)		-.019 (.011)	.001 (.001)
Shared time with biol. mother	.005*** (.001)		.000 (.001)	.000 (.001)	.005*** (.001)		.001*** (.001)	.000 (.001)
Shared time with father-in-law	.001 (.001)		.000 (.001)		-.000 (.002)		.009 (.001)	
Shared time with biol. father	.005*** (.001)		.001 (.001)		.005*** (.001)		-.001 (.002)	
Age at 1st childbirth		-.085*** (.010)	-.084*** (.010)	-.085*** (.010)		-.083*** (.011)	-.082*** (.011)	-.085*** (.010)
Age at last childbirth		.068*** (.003)	.068*** (.003)	.068*** (.003)		.065*** (.003)	.065*** (.003)	.068*** (.003)
Year's married until age of 45		-.010+ (.001)	-.017+ (.001)	-.017+ (.010)		-.018 (.011)	-.019 (.011)	-.018+ (.010)
Birth cohort	-.002*** (.000)	-.001** (.000)	-.001** (.000)	-.001** (.000)	-.000 (.000)	.001* (.000)	-.001+ (.000)	-.001** (.000)
Birth rank	.012* (.005)	.009+ (.005)	.009+ (.005)	.009+ (.005)	.006 (.005)	.003 (.006)	.003 (.006)	.009+ (.005)

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '+'

Multiple-failure Cox regression analysis

The effect of natal and in-law parents and sibling is estimated in three model versions (clustered on the family level; clustered on the family level without singlets; stratified on the family level) in five sets of models which differ regarding the inclusion of controls (raw effects, other kin, reproductive & individual controls, all controls). The raw models include only the categorical information about the respective kin of interest. The model series "other kin" include the information about other kin; e.g. whether mother, father, and siblings are alive. The model "reproductive controls" comprises the number of births, number of sons and daughters alive, as well as the dummy information whether the latest born child has died. Individual controls comprise birth rank, birth cohort and the socio-economic status of the current marriage. The models of interest are summarized in coefficient plots 1 to 8.

Biological mother and father

The Cox regression models do not suggest that there is a statistically significant association between the length of interbirth intervals and the presence of the biological mother (Figure 1a). Her death did also not affect the interbirth intervals (Figure 1b). Likewise, I find now association between the presence or alive status of the biological father and the length of his daughters' interbirth intervals (Figure 2a &2b).

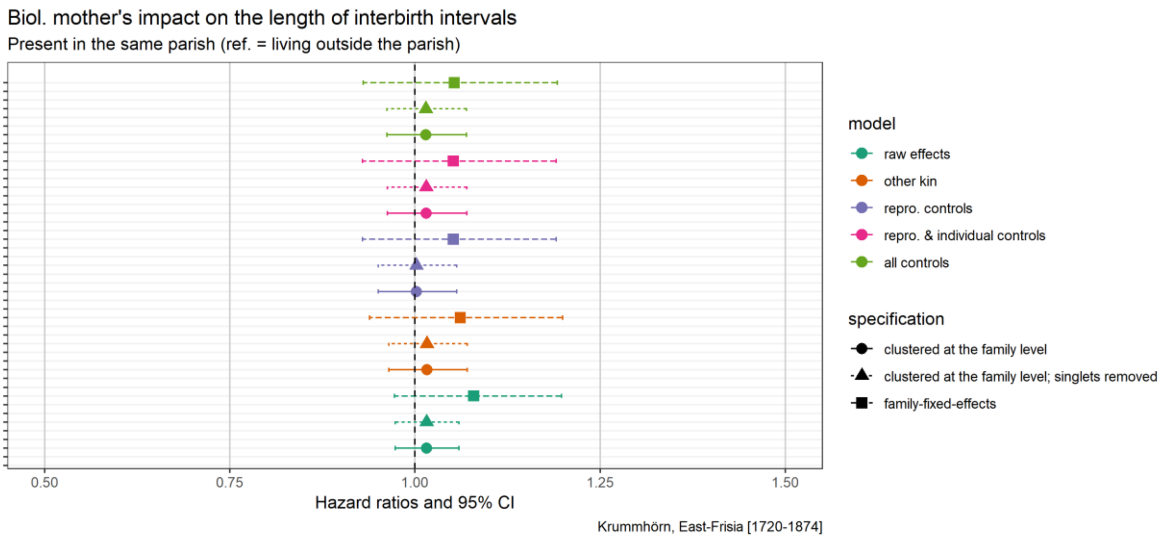


Figure 1a

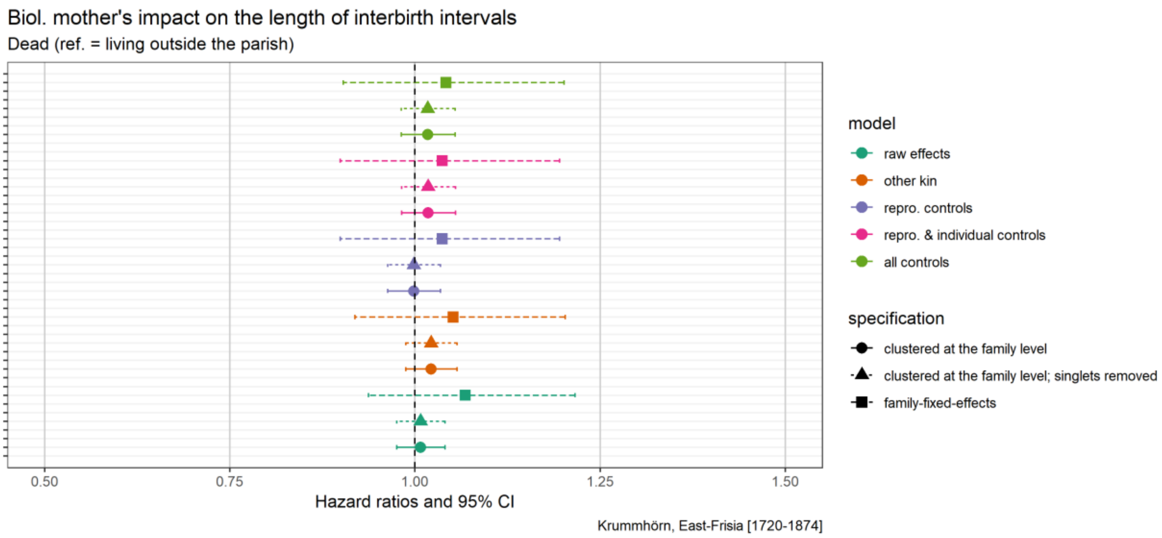


Figure 1b

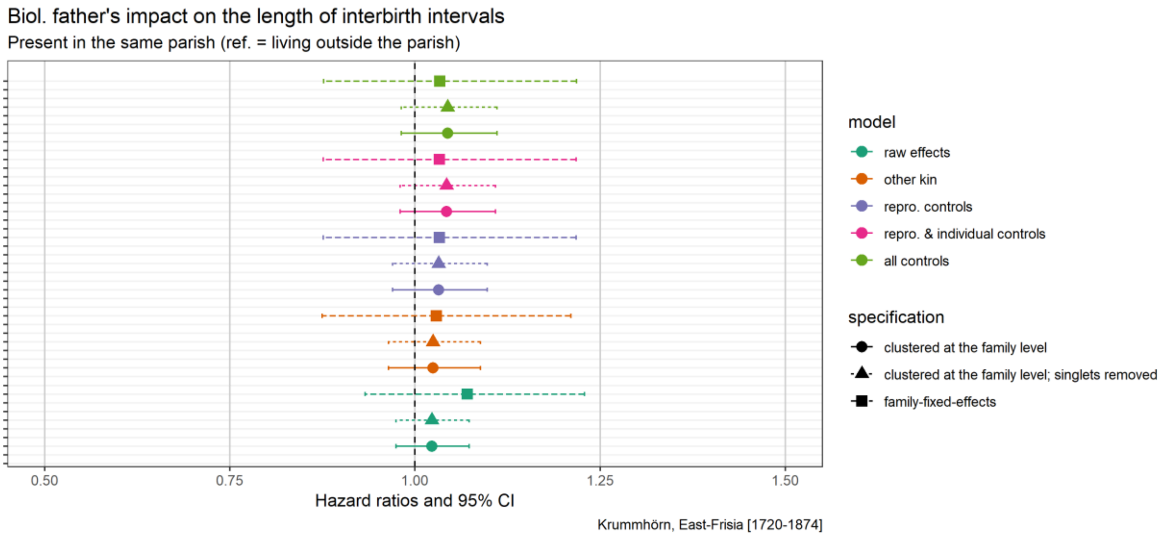


Figure 2a

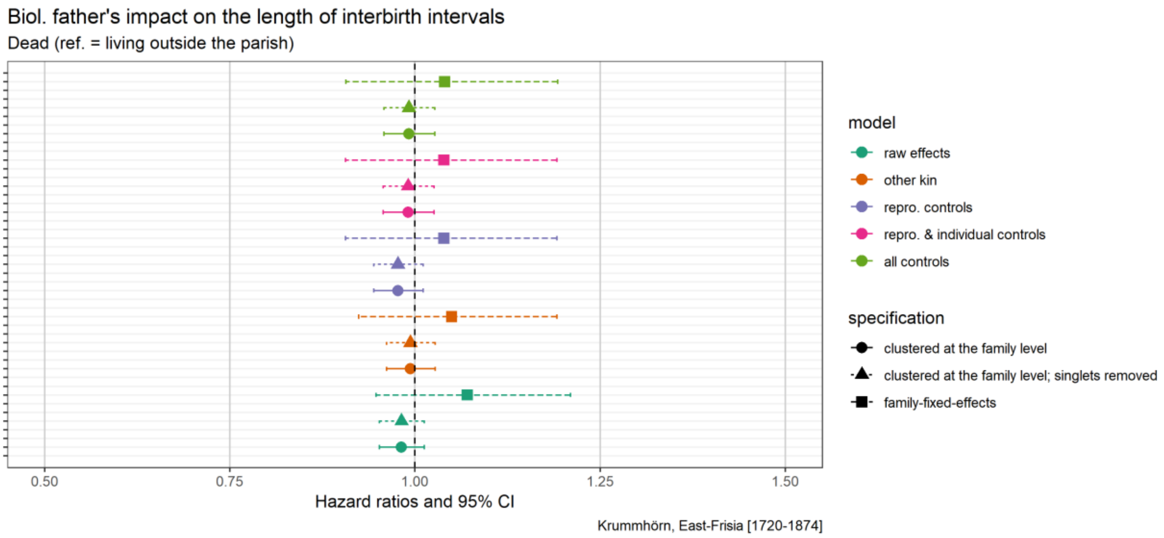


Figure 2b

Parents-in-law

The models suggest that the presence of the mother-in-law (Figure 3a) in the same parish is not statistically associated with the length of the interbirth intervals. All three model versions estimating the raw affect suggest that the death of the mother-in-law is deceleration her daughters-in-law's fertility, but all other models which include controls do not suggest that there is a statistically significant effect (Figure 3b). Likewise, some models suggest that the death of the father-in-law is associated with longer interbirth intervals (Figure 4b). However, the corresponding family-fixed-effect model version do not suggest a statistically significant association which implies that the association suggested by the clustered model version is due to unobserved characteristics shared between reproductive sisters. There is also no detectable association between father-in-law's presence and the interbirth intervals of their daughters-in-law (Figure 4).

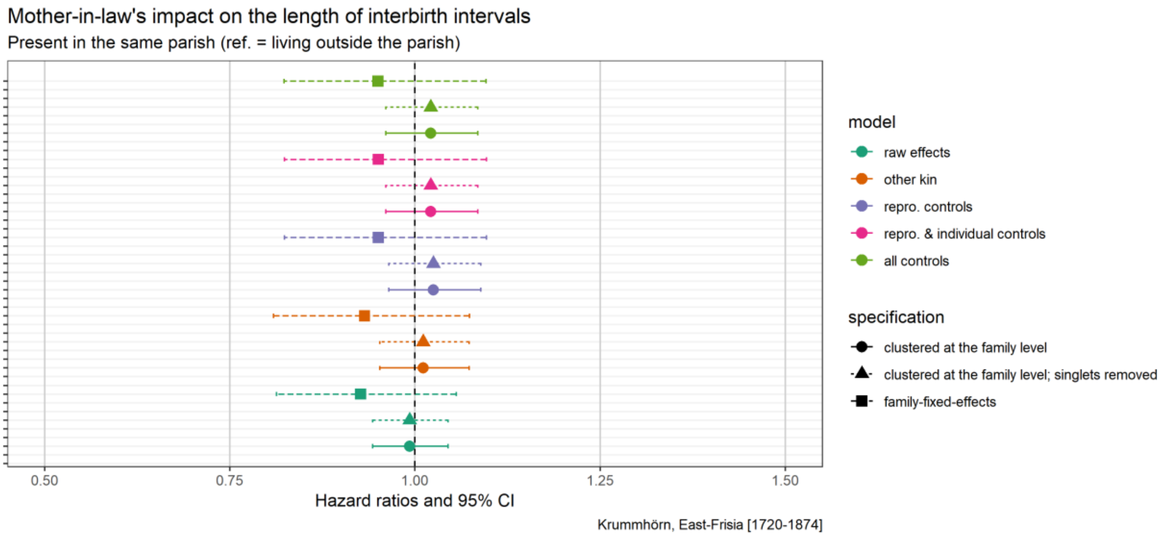


Figure 3a

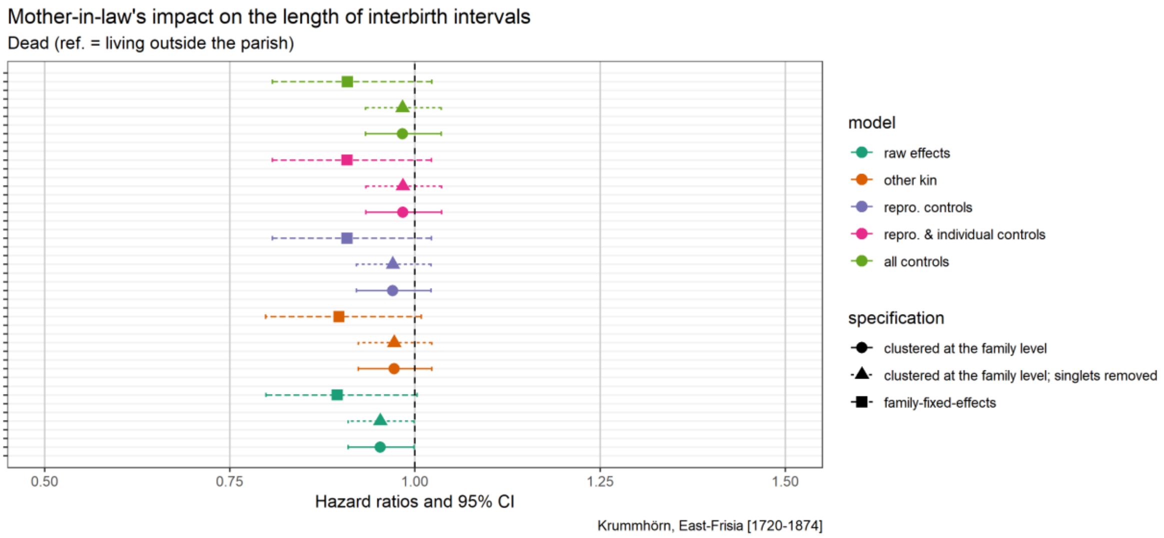


Figure 3b

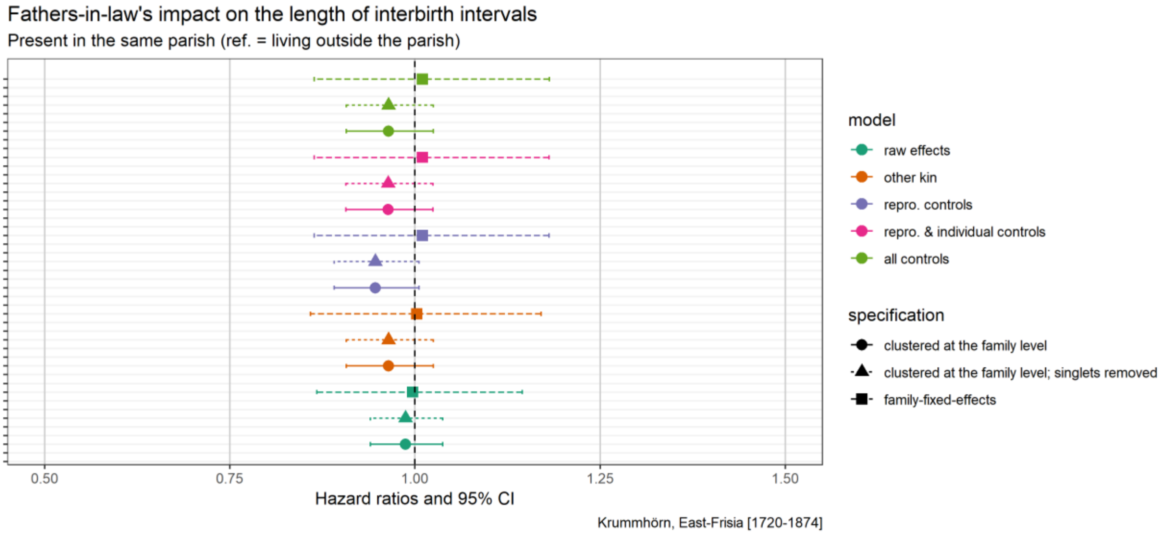


Figure 4a

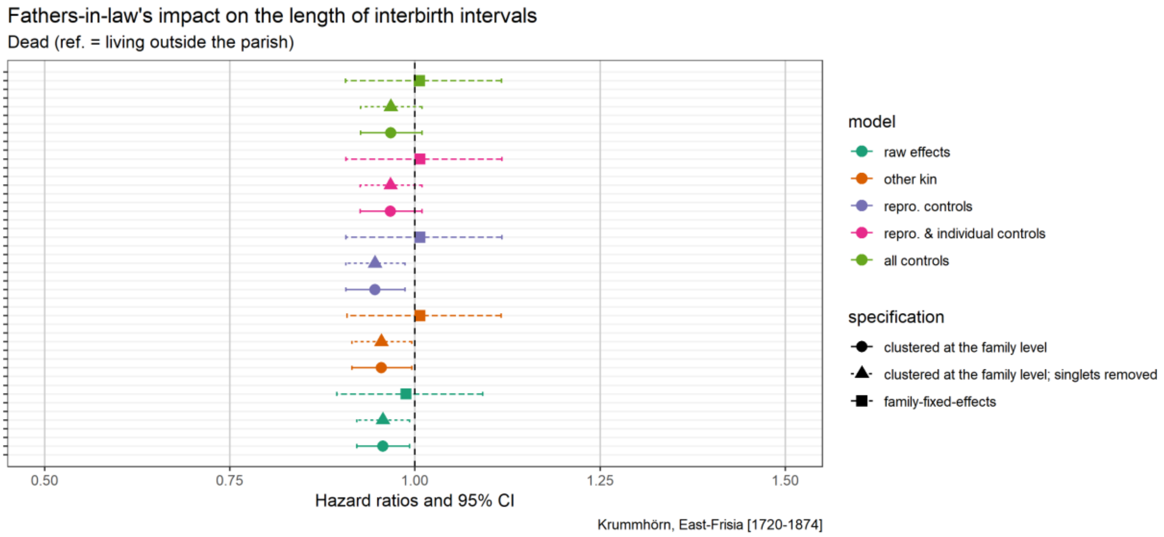


Figure 4b

Biological sisters

The Cox regression models suggest that the length of interbirth intervals was not statistically significantly affected, if reproductive females had no sisters somewhere in the Krummhörn or if these were living in the same parish.

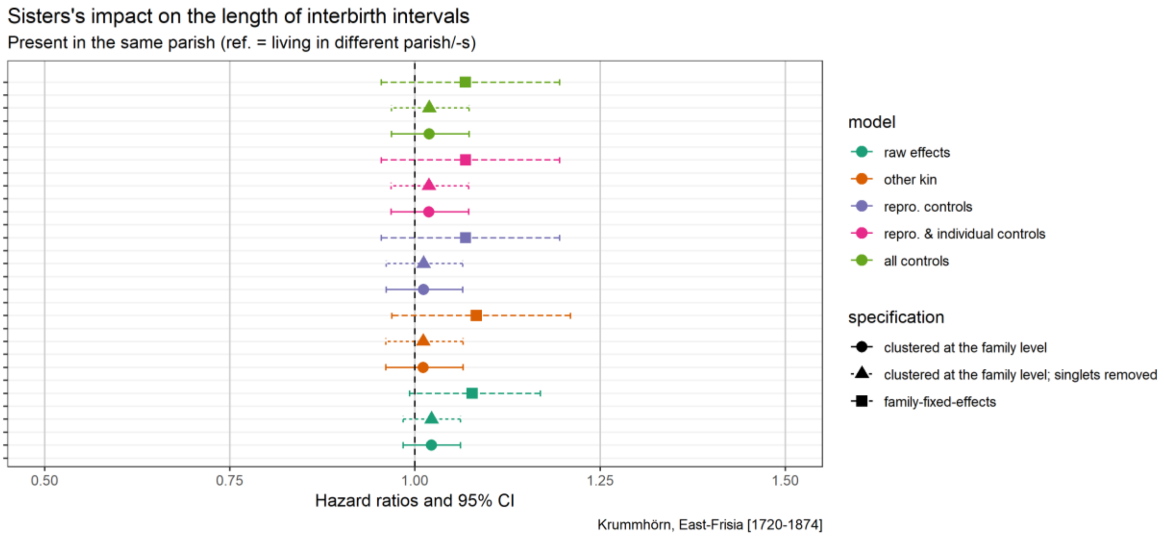


Figure 5a

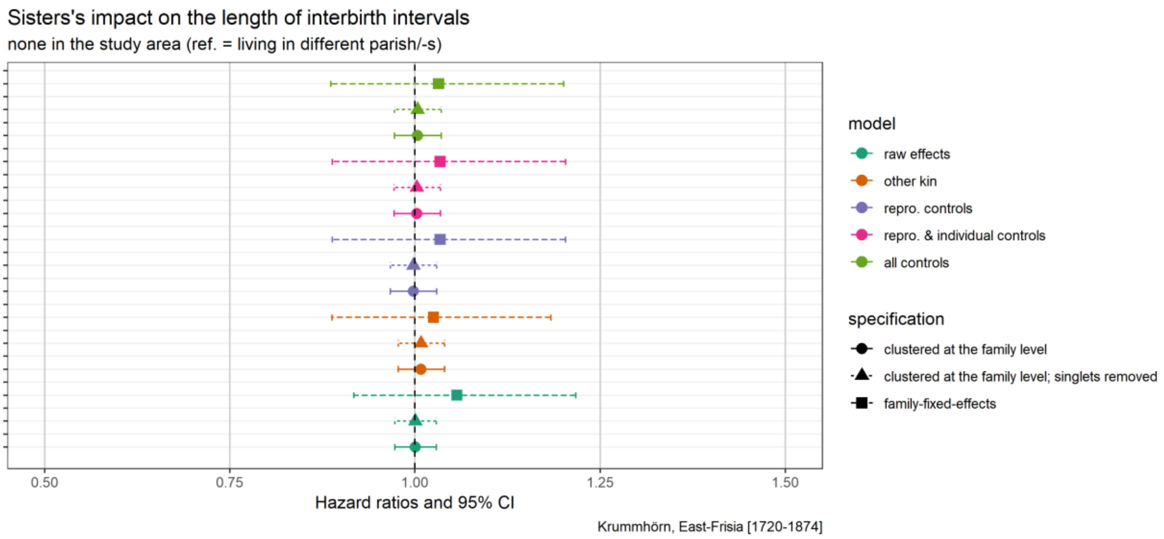


Figure 5b

Biological brothers

The Cox regression analysis suggests that interbirth intervals were not affected, if brothers were living in the parish in comparison to the reference category (Figure 6a). The clustered model versions also indicate no effect, if there were no brothers at all. However, the family-fixed-effect versions indicate that birth intervals were shortened by the absence of brothers in comparison to episodes in which the focal individual and/or her their reproductive sisters who had brother(-s) living abroad (Figure 6b).

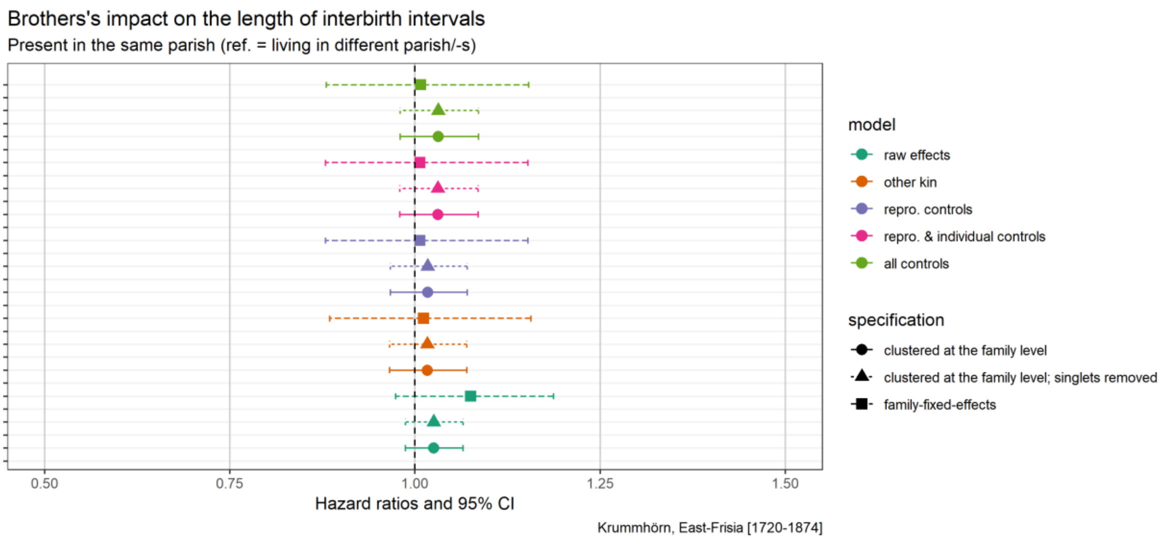


Figure 6a

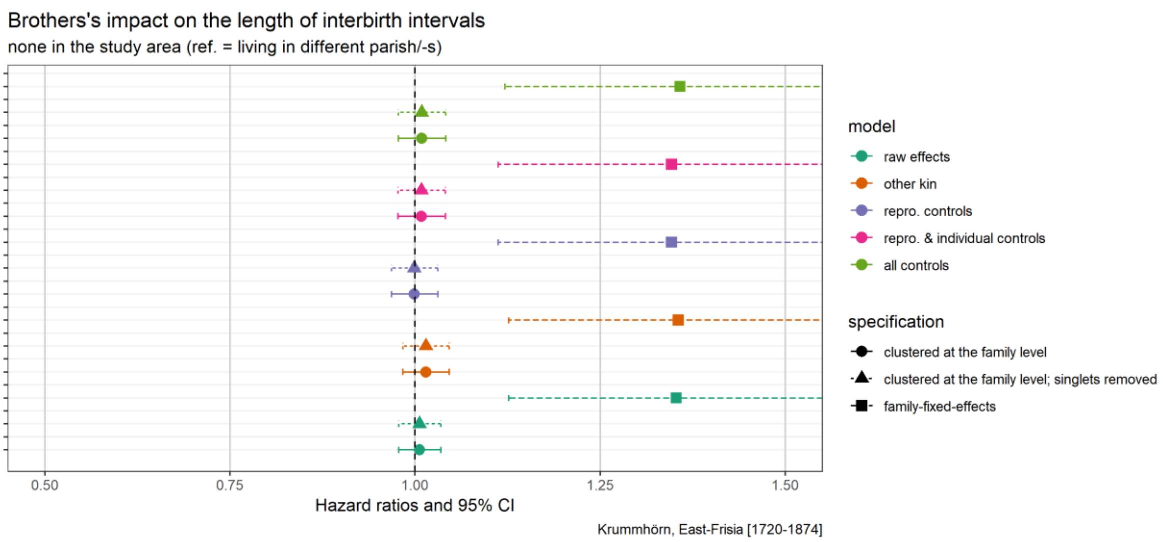


Figure 6b

Sisters-in-law

The Cox regression analysis does not suggest that interbirth intervals were affected if sisters-in-law were living in the same parish (Figure 7a). In the clustered model versions interbirth intervals were statistically significantly prolonged by the absence of sisters-in-law (Figure 7b). The corresponding family fixed-effect model versions estimate similar hazard ratios, although no statistically significance is suggested.

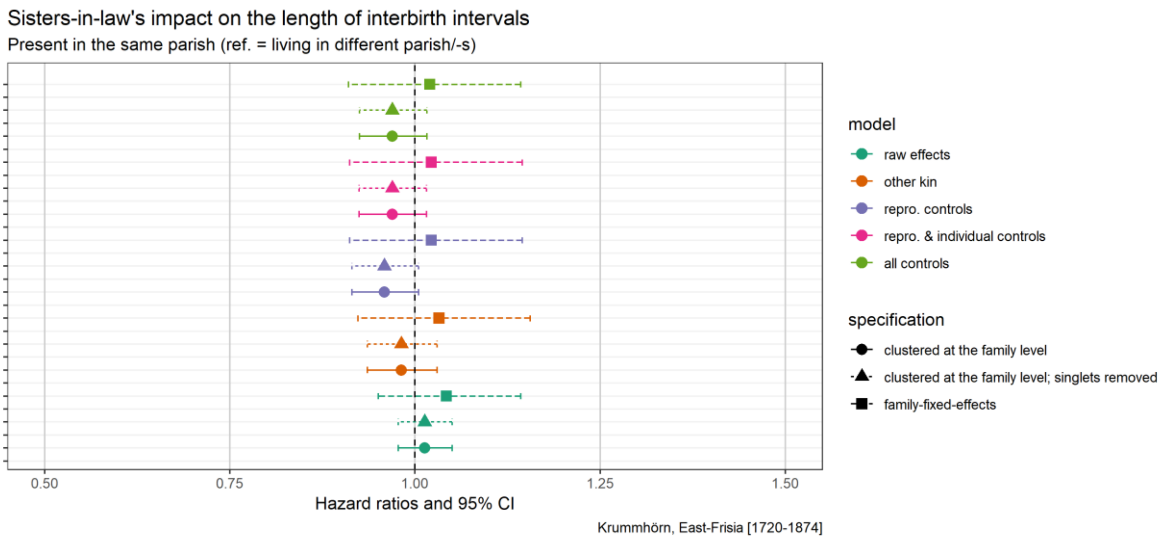


Figure 7a

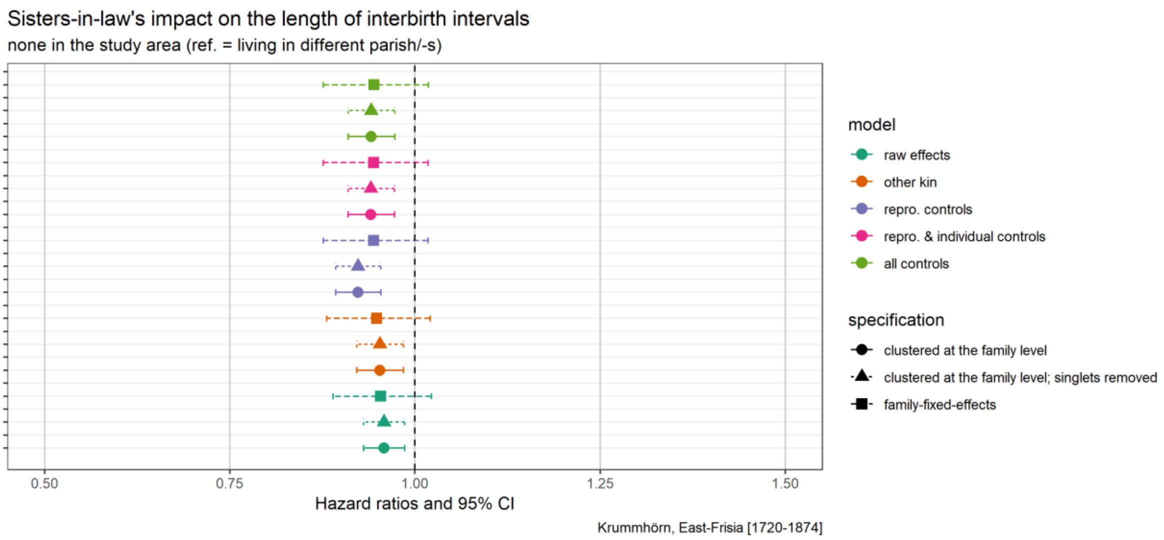


Figure 7b

Brothers-in-law

Both clustered model versions suggest that interbirth intervals were statistically significantly shortened, if brothers-in-law were living in the same parish (Figure 8a). However, the corresponding family-fixed-effect model version do not suggest a statistically significant association, which implies that the association suggested by the clustered model versions is due to unobserved characteristics shared between reproductive sisters. None of models suggest that interbirth intervals were affected, if there were no brothers-in-law in the study area (Figure 8b).

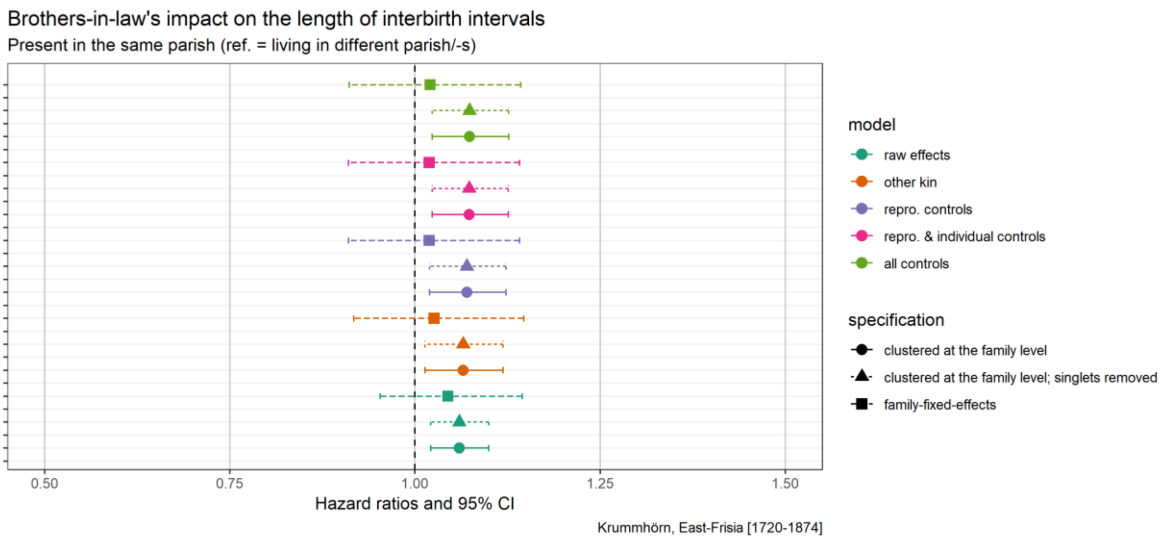
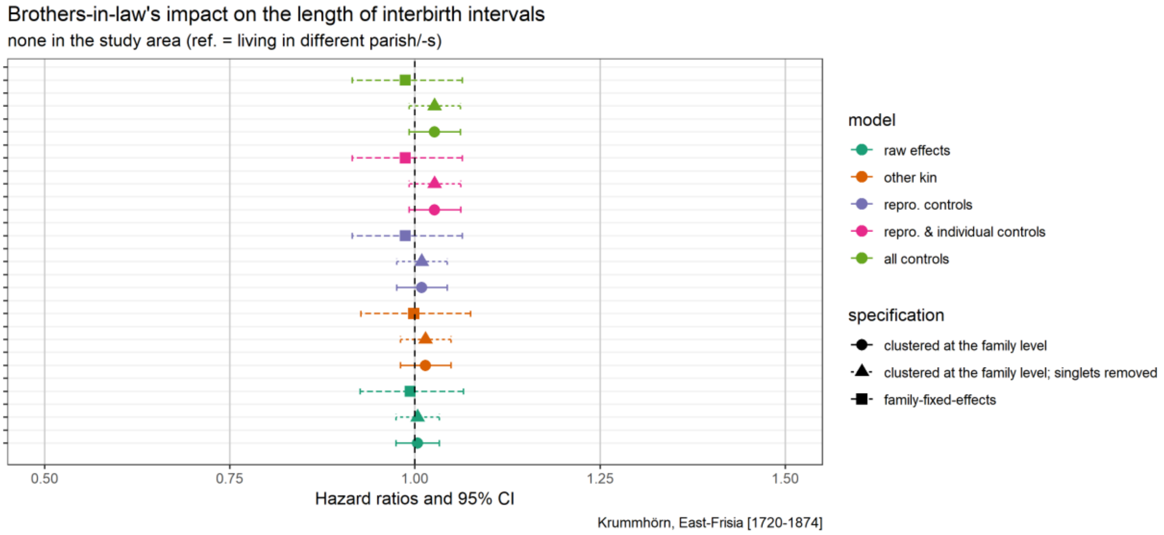


Figure 8a



Brothers-in-law's impact on the length of interbirth intervals
none in the study area (ref. = living in different parish/-s)
model
raw effects
other kin
repro. controls
repro. & individual controls
all controls
specification
clustered at the family level
clustered at the family level; singlets removed
family-fixed-effects
0.50
0.75
1.00
1.25
1.50
Hazard ratios and 95% CI
Krummhörn, East-Frisia [1720-1874]

Figure 8b

Discussion

The multiple-failure Cox regression suggests that the presence of kin in the same parish or in the region was not associated with the length of the interbirth intervals. The association between interbirth intervals and fathers-in-law living in another parish and between interbirth intervals and brothers-in-law's presence in the same parish are not suggested by the family fixed effect model versions which indicates that the association is due unobserved heterogeneity. Consistent with the indications of the Cox regression analysis, the Poisson regression analysis does not suggest that the number of births and the number of surviving children was affected by the survival of the biological parents or the parents-in-law. The fact that spatial proximity of kin and especially of the biological and in-law parents did not matter questions the importance of kin support in daily life for reproductive success in the early capitalistic society of the Krummhörn region.

It has been argued that humans are cooperative breeders (Hrdy 2009) and there is evidence that the presence of kin is associated with greater reproductive success (e.g. Tymicki 2006). This implies that individual reproductive success is affected by kin's motivation and likewise important by kin capability to support. Support hereby can be given in various forms ranging from knowledge transfers, e.g. how to breastfeed a child, to help in difficult life situation, e.g. after the loss a family member, to provision of constant assistance in daily childcare. It is therefore expected that the presence of kin who might exhibit an altruistic interest in mothers' prosperity because of close genetical relatedness is increasing fertility (e.g. Engelhardt et al. 2019) and/or maternal survival (Willführ et al. 2018). Especially post-generative maternal grandmothers might play a decisive role here since they might help their daughters with their reproductive activities (see grandmother hypothesis, Voland et al. 2005). Empirically, this association between helpful kin and reproductive success is less distinct than suggested by a naïve evolutionary approach to kin effects. Rotering and Bras (2015) found based on the historical population of the Netherlands that the presence of natal kin in the same household was not associated with shorter birth intervals or greater reproductive success. The findings by Rotering and Bras converge largely with the analysis presented here.

Kin selection theory predicts differential lineage effects on female survival and reproductive success. Female natal kin are not confronted with paternity uncertainty and can therefore expect inclusive fitness benefits, if they altruistically support their reproductive daughters, sisters, or niches. For this reason, the presence or the availability of female natal relatives is expected to be associated with increased reproductive success and maternal survival. Contrary, because of paternity uncertainty and the absence of close genetical relatedness members of the in-law family, and especially the mother-in-law might have a motivation to exploit her son’s wife both, reproductively and economically (Danielsbacka et al. 2011; Euler & Weitzel 1996). The presence of the mother-in-law therefore might indeed exhibit a fertility promoting effect (e.g. shorter interbirth intervals), but not for the good of her daughters-in-law. Such exploitation scenarios are expected to be absent or distinctly weaker among consanguineous marriages. Within consanguineous marriages, e.g. in marriages between first degree cousin, one of the parent-in-law is a biological aunt or uncle (Willführ et al. 2018). However, the results of the Cox regression analysis changed only marginally when the information was included as a dummy variable whether the union was known to be consanguineous. The same was found when I included interaction terms between the categorical information about the parents-in-law and consanguinity. Since I found no evidence for kin effects in close spatial proximity, the absence of consanguinity effects is not surprising.

Another aspect which often is only glimpsed is the methodical approach how kin availability is measured. If the impact of kin presence in close spatial proximity is estimated in relation to absence due to death, the test category includes both the effect of kin survival and kin presence. I argue that the effect of kin presence needs to be estimated against kin absence not against kin loss. Of course, the application of such a reference category comes with other flaws, e.g. the reasons why the respective kin is living somewhere else, but the unconcerned application of the reference “kin deceased” might substantially disguise the “true” effect of kin availability.

However, I do not believe that the findings of the present study are contradicting the necessity of an evolutionary perspective on kin behavior. I have three main arguments for this conclusion: Firstly, the people of the Krummhörn were not naturally fertile and after what we know these people were pursuing an optimal family size. This is also reflected by the Cox regression analysis of this study since the number of sons and daughters alive were associated with prolonged interbirth intervals at the highest level of statistical significance (see full models in the appendix). Kin effects on child survival therefore might have been more important than kin effects on number of births. Studies using the same population found differential effects of presence of maternal and paternal grandmothers (mothers-in-law) on infant survival (Voland & Beise 2000).

Secondly, the Krummhörn population grew only marginally during the study period and this was mainly caused by constant outmigration of young adults who were not successful or willing to make living within the region. The support of kin and likewise the competition between kin for building an economic basis of life and family might had been substantial. Social positioning, e.g. intergenerational transmission or inheritance of occupation or property and farmland, and other nepotistic activities could have effectively increased child's chances to successfully found a family within the region. This perspective fits also with the known increased sibling competition (Fox et al. 2017) and especially daughters competed over marriages (Beise & Voland 2008). For the Krummhörn case, kin support might have been more important for the foundation of a family than to support reproductive couple in daily life. The future research on kin effects on fertility in the Krummhörn region therefore will focus how kin affected marriage probability and marriage timing.

Thirdly, kin availability due to close spatial proximity does not necessarily reflect good living conditions and opportunities. Especially co-residence of many members of the natal family might be associated with poverty and other social issues (see 'nuclear-hardship' hypothesis, Laslett 1988). The perspective here is that kin might be motivated and available to help, but because of low resources or reduced abilities their support and helping is not effective. This differentiation between motivations and abilities of kin interactions is largely ignored in the debate to on kin effects (Willführ et al., in press; Willführ & Dijk, in press). However, we will not increase our understanding of kin effects on human reproduction, if we do not make this differentiation in future research.

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