Reproductive behavior before the onset of the fertility transition: usage of the Cox regression and survival analysis for the study of birth intervals (case study of Jablonec, Bohemia, in the 18th century), authors: Ludmila Fialova, Klara Hulikova Tesarkova, Barbora Kuprova[1]

Motive for the study

Frequency of births in families and birth intervals could be taken as an indicator of the type of reproductive behavior. Among other, it is useful for monitoring a number of characteristics like tempo of family growth, level of reproductive health, or effects of infant mortality on fertility. One of the original aims of the study of birth intervals was evaluation of completeness of the studied parish registers (Henry 1967). The importance of birth intervals study is mentioned in many historical demographic works (e.g. Kuklo 2009). In classical studies usually only simple calculations of the lengths of the birth intervals according to birth parity or some other different explanatory variables were applied (e.g. Reher, Sanz-Gimeno 2007, Wrigley 1998), because the calculations are significantly data-, time- as well as labor-demanding.

The problem of large databases needed for the analysis and their relatively complicated processing could be at least partly eliminated by using modern statistical software. Recent papers dealing more with the methodological point of view mention usually the Cox regression as a suitable method for this type of analysis (e.g. Van Bavel and Kok 2004). Rise of the importance of modern methods (Cox regression, survival analysis etc.) in historical demography could be illustrated by many recently published papers (e.g. Sandström, Vikström 2015).

Goal of the paper and data used in the analysis

The aim of the paper is a detailed study of birth intervals in families before the onset of the fertility transition. The length of the birth intervals was influenced by many factors, the most important of them are described in the study and their possible influence was estimated. Through the analysis it is possible to describe the reproductive behavior in historical families. The analysis is focused on data excerpted from individual records from parish registers from Jablonec nad Nisou (town in the northern part of the Czech lands). The analyzed period covers above all the 18th century (overlapping in the 17th and 19th centuries). In the analysis the possible influence of explanatory variables like birth parity, age of mother at marriage, age of mother at birth of child, reversal birth order, surviving of child of the previous order, total number of children born alive into a family is considered.

The database used in the analysis consisted of 2,366 families, where at least the information about year of marriage (1650–1872) was known. So as the analysis was not influenced by repeated marriages, where the reproductive behavior follows different patterns and regularities, only the bachelor/spinster marriages (in total 2,007 bachelor/sprinter marriages) were used in all the parts of the study. The analysis was applied to the birth intervals of all children born in the families in the database. There were records about 10,399 children, where at least the date of birth was known.

Methods

The descriptive and survival analysis was prepared separately for the mentioned explanatory variables. Then all the variables entered into one complex model – expressed using the Cox regression. That enabled to model the pure effect of all the variables adjusted for the various values of the other ones. In the analysis we excluded the first birth intervals (“marriage-birth”), what means that only birth intervals for children of higher then 0 parity ("birth-birth" intervals) were studied. All the mentioned explanatory variables were used as categorical ones in the Cox model.

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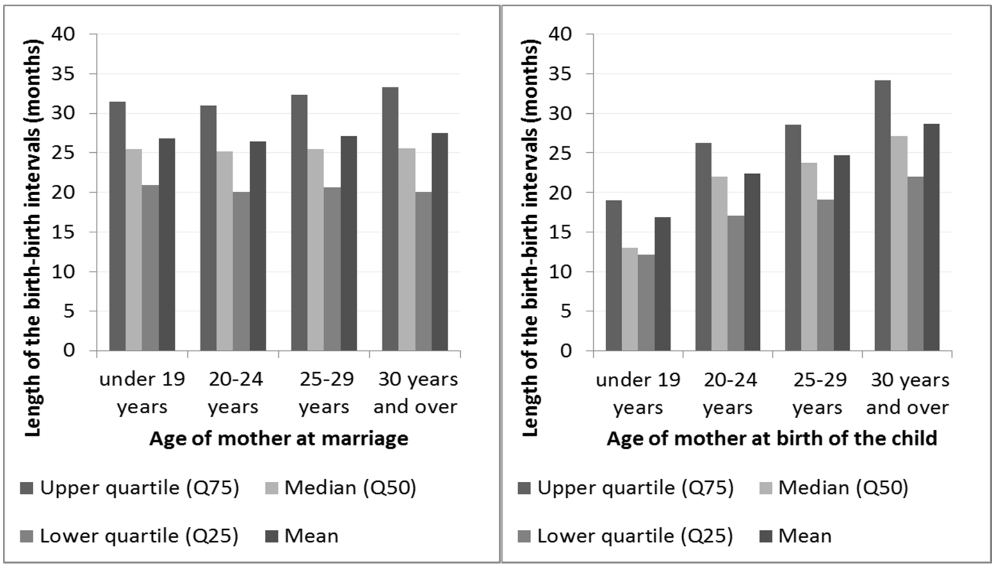
Selected important results

The average length of the birth-birth intervals almost did not differ according to different ages of women at marriage. Only for females who got married at age 25 and more years the values of the upper quartile are slightly increasing. The age of mother at birth of the child has significantly stronger effect on the length of the birth-birth intervals (Figure 1). The average length of the intervals increases with age of the mother. But we have to keep in mind that those results are not standardized for values of the other variables.

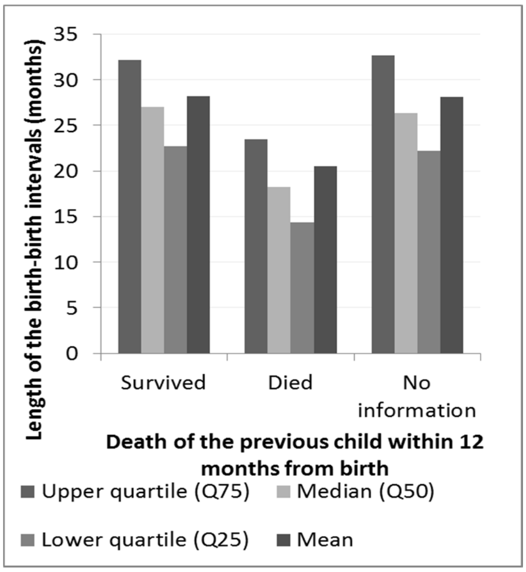
Figure 1: Upper and lower quartile, median and mode of the length of the birth-birth intervals according to age of mother at marriage (left) and age of mother at birth of the child (right)



Note: not standardized for values of other variables

According to the descriptive statistics the average length of the birth-birth intervals seems to be independent of the total number of children born alive into a family. The difference is visible only for families where 8 and more children were born. Significant differences could be observed according to the reversal birth order of the child (calculated from the last one born in a family). The last children were born on average with the longest birth intervals from the previous child. However, also in this case we have to keep in mind that the results are not standardized for values of the other variables.

Figure 2: Upper and lower quartile, median and mode of the length of the birth-birth intervals according to survival of the previous child during the first 12 months of life



Note: not standardized for values of other variables

Probably the most important variable for influencing the average length of the birth-birth intervals was the survival of the previous child in a family. According to the simple descriptive statistics the average birth intervals are nearly the same in case that the previous child survived the first year of life as well as in case that we have no information about the survival of the previous child (i.e. the category "no information" probably represents above all the survived children; see Figure 2). On the other side, when the child of the previous order died within 12 months after the birth, then the average birth interval to the next child was significantly shorter.

Using the more complex Cox regression model it is possible to estimate the influence of all the explanatory variables mentioned above. We used 5,588 observations for the model (i.e. observations where values of the explanatory variables are known and where the birth order of the child is higher than 1). All the variables showed to be statistically significant in the model on at least 1% level of significance.

Table 1: Parameter estimates and hazard ratios from the Cox regression

Parameter		Parameter Estimate	Pr > ChiSq	Hazard Ratio
Age of mother at marriage	under 20 years			
	20–24 years	0.29922	<.0001	1.349
	25–29 years	0.52957	<.0001	1.698
	30 years and over	0.63069	<.0001	1.879
Age of mother at birth of the child	under 20 years			
	20–24 years	-0.49578	0.0481	0.609
	25–29 years	-0.85579	0.0006	0.425
	30 years and over	-1.39910	<.0001	0.247
Number of life births in a family	2–3 children			
	4–5 children	-0.11329	0.0814	0.893
	6–7 children	-0.03245	0.6290	0.968
	8–9 children	0.21142	0.0034	1.235
	10 and more children	0.52879	<.0001	1.697
Reversal birth order of the child	the last child			
	2nd child from the last	0.25362	<.0001	1.289
	3rd child from the last	0.31782	<.0001	1.374
	4th child from the last	0.39924	<.0001	1.491
	5th child from the last	0.43149	<.0001	1.540
	6th child from the last	0.34453	<.0001	1.411
Survival of the child of previous order	survived 12 months			
	died within 12 months	0.81009	<.0001	2.248
	no information	-0.01586	0.6754	0.984

Note: the reference category was the first one for all the variables; grey values are significant on at least 5% level of significance

For the average length of the birth-birth intervals the age of mother at marriage showed to be significant as well as the differences among all the categories of this variable (Table 1). The average length of the birth-birth intervals is decreasing with age at marriage. This corresponds to the fact that the reproduction period was limited by the highest possible fertile age and age of marriage (because most of the children of the 2nd and higher order were born into a marriage). So as women who got married on average later were able to give birth to children of higher order, the birth-birth intervals had to be on average shorter.

The opposite effect is observable for the variable age of mother at birth of the child. The average length of the birth-birth intervals is increasing with age of mother at birth of the child. This result is consistent with biological assumptions of reproductive possibilities at higher ages. At the same time the result is adjusted for different values of the age of the mother at marriage and all the other variables.

Total number of children born alive in a family is significant for the average length of the birth-birth intervals beginning from the number of children equal to at least 8. In families with more than circa 8 life born children the average length of birth-birth intervals seems to be shorter. Again this result is consistent with the fact of the limited time of fertile period of a woman. Higher number of children has to be born with shorter average intervals between the births.

The reversal birth order also showed to be important for the explanation of the modelled variable. From the analysis it showed that the last child in a family was on average born with the longest birth-birth interval and the length of the birth-birth intervals decreased with increasing values of the reversal birth order.

Probably the strongest effect for the average length of the birth-birth intervals could be observed for the variable representing survival of the child of previous order. In case that the previous child died within 12 months after the birth, we could see significant shortening of the birth interval in comparison to situation when the previous child survived the first year of life. On the other side, the last category of this variable (where we have no information about surviving of the previous child) is not statistically different from the situation where the previous child survived the first year of life. As was mentioned above, based on this result we can suppose that most of the children, where we have no information about their survival, in fact survived the first year of their life.

Discussion and conclusion

The paper consists of application of selected contemporary analytical methods (above all the Survival analysis and the Cox regression) to historical individual data. Thanks to that, the classical methods of historical analysis and their conclusions could be discussed in comparison to more detailed results. In this way the importance of methodological approaches is revealed. Above all, it will be discussed for which aims the different analytical methods could be of particular importance. Through the application of the Cox regression and the Survival analysis of large data sets of individual life histories several new and not yet fully described factors affecting the length of birth intervals were revealed.

Moreover, the studied data set represents a rather unique large representation of families living before the onset of the fertility transition and conscious fertility influencing in the area of the Central Europe. The study enables to compare the results with similar ones made for other localities.

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