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Fertility Transition in 19th-20th Century Estonia: An Individual Level Perspective

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Abstract: Fertility transition has yet to accumulate a large set of studies with individual level data to allow to make wide generalizations. Recently the availability of data has become better. The current thesis is one step in the direction of looking into the fertility transition as a whole with individual level data and by using event-history methods on the case of Estonia.

The study takes the cohort perspective to find out which birth cohorts at which parities started the fertility transition, what were the different paths taken by urban and rural populations and how did birth spacing change over time.

We use register data collected by the First Estonian Republic, which has the fertility histories of birth cohorts of Estonian women born between 1845 and 1919, and fertility processes lasting until the year 1949. We analyse these with piece-wise constant survival models separately for each parity; having birth cohort, urban-rural residency and piece-wise constant durations since previous birth as the main variables.

We find that that probability to next birth starts to decline earlier for the higher parities and moves to lower parities for later cohorts. For parities 3-7 women born in 1873-1880 are first with significantly lower hazard to next birth. For parity 2 the 1880-1887 birth cohort starts the transition. All parities contribute to the fertility decline. For the urban population the fertility decline is greater in proportion and also lasts less in birth cohorts, while for the rural population the decline is more gradual and lasts longer. In the birth spacing dimension we find that the average interval between births became shorter over time across all parities, and for both the urban and the rural population.

Contents

1 Introduction **8**

2 Demographic Transition Theory and concepts related to fertility **10**

2.1 Fertility change and the Demographic Transition theory 10
2.2 Natural fertility and fertility stopping 12
2.3 Adjustment or innovation? 14
2.4 Criticism of the Princeton project 17
2.5 Spacing 18
2.6 Stopping and spacing in recent studies 20

3 Previous evidence of fertility transition in Estonia **24**

3.1 Backdrop 24
3.2 Fertility transition in the context of Russia 25
3.2.1 Fertility 26
3.2.2 Effects of nationality and infant mortality rate 27
3.2.3 Nuptiality 28
3.3 Transition at county level 28
3.4 Summary 29

4 Research question **31**

5 Data and methods **33**

5.1 Data 33
5.2 Method 35
5.3 Model and variables 36

6 Results **40**

6.1 Descriptives 40
6.2 Initial piece-wise constant model 42
6.3 Interaction between urban-rural residency and cohort 46
6.4 Interaction between cohort and duration since last birth 49

7 Conclusion **54**

8 Acknowledgements **57**

References **58**

A Appendix **62**

A.1 Descriptives 62

A.2 Estimation results 65

List of Tables

1 Mean number of children born, children alive, and percentage of children dead for Estonian women by birth cohorts from 1845 to 1919 42

2 Initial survival models for each parity (or parity-pair) using piece-wise constant durations after birth, cohort, urban-rural residency and mother's age-group as categorical variables (E1) 44

3 Mean number of children born, children alive, and percentage of children dead among non-childless Estonian women by birth cohorts from 1845 to 1919 62

4 Mean age by parity for Estonian women by birth cohorts from 1845 to 1919 63

5 Number and proportion of Estonian women remained childless at death or censored, birth cohorts from 1845 to 1919 63

6 Number and proportion of births for Estonian women by urban-rural residency, birth cohorts from 1845 to 1919 64

7 Number and proportion of births for Estonian women by marital status, birth cohorts from 1845 to 1919 64

8 Interaction between urban-rural residency and cohort (E2) 65

9 Interaction between cohort and duration since last birth (E3) 66

10 Interaction between urban-rural residency, cohort and duration since last birth (E4) 68

List of Figures

1 Hazard ratios on transition to parity 2 across birth cohorts. Estonian women born in 1845-1919, risk relative to 1880-1887 cohort (E1). 45

2 Hazard ratios on transition to parity 3 across birth cohorts. Estonian women born in 1845-1919, risk relative to 1880-1887 cohort (E1). 45

3 Hazard ratios on transition to parities 4 and 5 across birth cohorts. Estonian women born in 1845-1919, risk relative to 1880-1887 cohort (E1). 45

4 Hazard ratios on transition to parities 6 and 7 across birth cohorts. Estonian women born in 1845-1919, risk relative to 1880-1887 cohort (E1). 45

5 Hazard ratios on transition to parity 2 across birth cohorts by urban-rural residency. Estonian women born in 1845-1919, risk relative to 1880-1887 rural cohort (E2). 48

6 Hazard ratios on transition to parity 3 across birth cohorts by urban-rural residency. Estonian women born in 1845-1919, risk relative to 1880-1887 rural cohort (E2). 48

7 Hazard ratios on transition to parities 4 and 5 across birth cohorts by urban-rural residency. Estonian women born in 1845-1919, risk relative to 1880-1887 rural cohort (E2). 48

8 Hazard ratios on transition to parities 6 and 7 across birth cohorts by urban-rural residency. Estonian women born in 1845-1919, risk relative to 1880-1887 rural cohort (E2). 48

9 Hazard ratios by birth cohorts at piece-wise constant durations after birth on transition to parity 2. Estonian women born in 1845-1919, risk relative to 1845-1864 cohort at 18-24 months after birth (E3). 52

10 Hazard ratios by birth cohorts at piece-wise constant durations after birth on transition to parity 3. Estonian women born in 1845-1919, risk relative to 1845-1864 cohort at 18-24 months after birth (E3). 52

11 Hazard ratios by birth cohorts at piece-wise constant durations after birth on transition to parities 4-5. Estonian women born in 1845-1919, risk relative to 1845-1864 cohort at 18-24 months after birth (E3). . . . 52

12 Hazard ratios by birth cohorts at piece-wise constant durations after birth on transition to parities 6-7. Estonian women born in 1845-1919, risk relative to 1845-1864 cohort at 18-24 months after birth (E3). . . . 52
13 Kaplan-Meier survival curves on transition to parity 2. Estonian women born in 1845-1919 by birth cohorts. 53
14 Kaplan-Meier survival curves on transition to parity 3. Estonian women born in 1845-1919 by birth cohorts. 53
15 Kaplan-Meier survival curves on transition to parities 4 and 5. Estonian women born in 1845-1919 by birth cohorts. 53
16 Kaplan-Meier survival curves on transition to parities 6 and 7. Estonian women born in 1845-1919 by birth cohorts. 53
17 Hazard ratios at piece-wise constant durations after birth on transition to parity 2 by urban-rural residency for cohort 1845-1864. Risk relative to rural population at 18-24 months after birth (E4). 70
18 Hazard ratios at piece-wise constant durations after birth on transition to parity 2 by urban-rural residency for cohort 1864-1883. Risk relative to rural population at 18-24 months after birth (E4). 70
19 Hazard ratios at piece-wise constant durations after birth on transition to parity 2 by urban-rural residency for cohort 1883-1902. Risk relative to rural population at 18-24 months after birth (E4). 70
20 Hazard ratios at piece-wise constant durations after birth on transition to parity 2 by urban-rural residency for cohort 1902-1921. Risk relative to rural population at 18-24 months after birth (E4). 70
21 Hazard ratios at piece-wise constant durations after birth on transition to parity 3 by urban-rural residency for cohort 1845-1864. Risk relative to rural population at 18-24 months after birth (E4). 71
22 Hazard ratios at piece-wise constant durations after birth on transition to parity 3 by urban-rural residency for cohort 1864-1883. Risk relative to rural population at 18-24 months after birth (E4). 71
23 Hazard ratios at piece-wise constant durations after birth on transition to parity 3 by urban-rural residency for cohort 1883-1902. Risk relative to rural population at 18-24 months after birth (E4). 71

24 Hazard ratios at piece-wise constant durations after birth on transition to parity 3 by urban-rural residency for cohort 1902-1921. Risk relative to rural population at 18-24 months after birth (E4). 71
25 Hazard ratios at piece-wise constant durations after birth on transition to parities 4-5 by urban-rural residency for cohort 1845-1864. Risk relative to rural population at 18-24 months after birth (E4). 72
26 Hazard ratios at piece-wise constant durations after birth on transition to parities 4-5 by urban-rural residency for cohort 1864-1883. Risk relative to rural population at 18-24 months after birth (E4). 72
27 Hazard ratios at piece-wise constant durations after birth on transition to parities 4-5 by urban-rural residency for cohort 1883-1902. Risk relative to rural population at 18-24 months after birth (E4). 72
28 Hazard ratios at piece-wise constant durations after birth on transition to parities 4-5 by urban-rural residency for cohort 1902-1921. Risk relative to rural population at 18-24 months after birth (E4). 72
29 Hazard ratios at piece-wise constant durations after birth on transition to parities 6-7 by urban-rural residency for cohort 1845-1864. Risk relative to rural population at 18-24 months after birth (E4). 73
30 Hazard ratios at piece-wise constant durations after birth on transition to parities 6-7 by urban-rural residency for cohort 1864-1883. Risk relative to rural population at 18-24 months after birth (E4). 73
31 Hazard ratios at piece-wise constant durations after birth on transition to parities 6-7 by urban-rural residency for cohort 1883-1902. Risk relative to rural population at 18-24 months after birth (E4). 73
32 Hazard ratios at piece-wise constant durations after birth on transition to parities 6-7 by urban-rural residency for cohort 1902-1921. Risk relative to rural population at 18-24 months after birth (E4). 73

1 Introduction

In the current thesis we study the fertility transition in Estonia in the dimension of urban-rural residency, birth order and duration since last birth, using individual level data and event-history methods.

Past research on the First Demographic Transition and more specifically the fertility component has used aggregate methods to study the topic. Estonia has been looked at in context of tsarist Russia (Anderson, Coale, and Härm 1979) and at regional level of counties (Katus 1994a,b), in both cases employing the Princeton project's fertility indices. As the use of these for purposes other than crude descriptives has been criticised, it would be worthwhile to compare to findings obtained by using micro-data and survival modeling. There doesn't appear to exist a standard way of doing this– similar to how the Princeton project used aggregate methods on the whole of Europe –therefore, we explore this space with some relatively straight-forward hazard models. Similar to the Princeton's book on Russia, we will use the urban-rural dimension to describe and compare the transition in Estonia.

The research question is: how did the fertility transition progress in terms of birth order, birth cohorts, urban-rural residency, and birth spacing. To find this out we run a set of piece-wise constant survival models for parities 2 to 7 using cohorts of Estonian women born between 1845 to 1919, process of study ending at 1949. Therefore the analysis covers the whole of fertility transition.

The background for the thesis is the fertility component of the First Demographic Transitions theory, its main concepts and open issues, especially the conceptual pairs of stopping-spacing and adjustment-innovation. We discuss these topics in past and recent research in section 2. In section 3 an overview of research on Estonia's fertility transition is given. The remaining parts of the thesis will set the research question in detail, describe the data and methods, and then present the results.

Our study is the first in using individual level data on the fertility transition in Estonia and adds to the short list of papers on this topic for Estonia.

The thesis also improves on previous research in that it is one of few that tries to look at the whole of fertility transition with individual level data and event-history methods. There are multiple improvements that these two give which aggregate level analysis lacks. Statistics derived from aggregates have by definition already lost detail on the process they describe. As there are cases where two or more forces pull the aggregate in opposite directions then these can mask each other out to a level of leaving little traces in the aggregate itself. This happened with the Princeton's indices to some degree, we discuss more in section 2.4.

The advantage of event-history analysis is that it synthesizes many useful statistical techniques, and includes all of their benefits (and, unfortunately, the data requirements). The method allows to conveniently separate effects of multiple variables, similar to regression analysis, and also adds a time-to-event dimension to better accord to the actual process of study, which is time to conception in our case. Put together, the methodology makes full use of the data on the individual level while controlling for group differences.

2 Demographic Transition Theory and concepts related to fertility

2.1 Fertility change and the Demographic Transition theory

The broad picture of global demographic developments and within that, of fertility has in the past half of century been mostly the same – the one that has become known as the First Demographic Transition, developed already in 1930s by Warren Thompson, but finalized as theory by Kingsley Davis and Frank Notestein in 1945 (Davis 1945; Kirk 1996; Notestein 1945). The theory maintains that the world's population had a near-zero growth rate until about three hundred years ago, when its population, led by Europe, started rapidly growing. The precondition for this was reduction in mortality, which lifted the pressure from societies to keep fertility high. The process divides crudely into four stages: (1) constantly high mortality and fertility, (2) lowering mortality, (3) lowering fertility, and (4) constantly low mortality and fertility. In stages 1 and 4 there is little growth in population size, while in stage 2 the population increase accelerates to some maximum, and during 3 it decelerates. Stage 1 said to be in high pressure state– the high force of mortality counterbalanced by high force of fertility –, and stage 4 in low pressure state – same forces in balance, weaker in strength.

As by all such generalizations, the details of the progression have been bound to vary by geographic area and social stratum. France is probably the most proponent example of where decline in mortality almost coincided with the one in fertility, thus leading to a modest growth in population size. Besides France there have been other exceptions from the common pattern, e.g the nobility of England, France and Italy, the bourgeoisie Geneva, and in Jewish populations of some cities in Italy where fertility was low even before the transition (Coale 1986). But not only elite groups have been identified with low fertility pre-transitionally: Wrigley found traces of fertility control in the villages of England (Wrigley 1966), and Demeny in villages of southern Hungary (Demeny 1968).

In Notestein's original formulation, he stated that there is no other reason for high fertility than an equally high mortality, as without producing at least enough as there are dying any population would soon wither (Notestein 1945). Or, as Ansley Coale put it, that historic populations where fertility was lower than mortality over a longer period of time are all extinct (Coale 1986).

The axiom on which Notestein built his theory is that (to state the basics) it is in human nature to "prefer health to sickness and life to death" (Notestein 1983, p. 348). So, prior to the transition, populations only lacked the means for living longer, but the motivation was always there. As in the past mortality was high, norms and institutions of any surviving population had to counter with at least equally high fertility. When better health and longer life became possible, a "demographic explosion" almost inevitably had to follow because of the inertia of those norms. But as larger proportions of children reached their adulthood, norms promoting high fertility eventually changed, too (Notestein 1983).

The benefit of a small family was identified already in 1890 by Arsène Dumont as "social capillarity", as to raise one's social position (to "climb the capillary") it was advantageous to have less children (Kaa 1996, p. 399). By seeing how low mortality made conceiving a much smaller number of children possible, in 1965 Notestein declared his theory universally applicable: everywhere, where socio-economic development reaches a degree of lowering mortality, an inevitable reduction in fertility has to follow. And indeed, this has been the case in all of the world's populations (Notestein 1983, p. 351).[1]

The story of the First Demographic Transition was subsequently studied in a variety of geographic areas, focusing on its many different aspects of when, why and how it happened, trying to pin down the exact sequences of cause-and-effect of how behaviors changed, and how they were related to other processes in society. The symptoms of the demographic transition are not debated, but causal paths driving it continue to be – the majority of attention being received by what caused the fertility decline.[2]

[1]This has been true with the addition that the later the transition starts, the more drastic has it been in terms of population growth. Western Europe never experienced a growth larger than 1% per year, but developing countries today reach rates of 2-4% (Notestein 1983).

[2]Decline in mortality has been perceived as easier to explain by the usual suspects of the emergence of modern state with public order, developments in agricultural techniques and technology, improvements in hygiene and medicine, etc. Even so, there has been debate there as well – for an review see Bengtsson 2003.

2.2 Natural fertility and fertility stopping

Although there existed previous research, most of the in-depth studies of the fertility change during FDT have been done since 1950s (Kaa 1996, p. 394), and so has the conceptual framework developed in that time.

In the beginning of that period a Frenchman, Louis Henry invented a central piece in this framework called *natural fertility*, introduced in 1953 (Henry 1953) and supported with empirical evidence in 1961 (Henry 1961). As Henry defined it, "control can be said to exist when the behavior of the couple is bound to the number of children already born and is modified when this number reaches the maximum which the couple does not want to exceed" (Henry 1961, p. 81). Thus, Henry's fertility control explicitly means deliberate *stopping* after a specific number of children. Stopping has also by different authors been called "parity-specific fertility control" or "family limitation", both pointing at a target size of family.[3] The relatively faster decrease in higher ages' fertility rates was used by Henry to detect stopping behavior, the method being to calculate age-specific fertility rates for a number of time series, observe the drop in rates for higher ages over these series (Henry 1961).

At the time of describing natural fertility, Henry found that different populations have *different* natural fertilities, where the highest found was 1.7 times that of the lowest. He originally saw two groups of reasons for this. The first was of physiology, where different populations have different fecundity characteristics; the second was behavioral, with ways of living that lower the probability to conception, such as breastfeeding or taboos for post-natal intercourse (Henry 1961). One could easily continue this list[4], but the main idea of natural fertility was its *indeliberacy*, i.e. the causes that create a certain natural fertility are outside of conscious choice and family planning was not used.

The methods to predict natural fertility for any population were subsequently developed by others. Bongaarts, and later Hobcraft and Little constructed a list

[3]The use of the word of "parity" seems to come from its French origin meaning as symmetry or equality, where the numbers compared are the one of children wanted, and the other of children alive. The family wants one to equal the other – thus parity-specific fertility control (not to have more children) starts when the numbers are equal.

[4]Seasonal labor migration, diet composition leading to higher or lower potency, and so on. It is only important that they are indeliberate – consequences of something else.

of proximate variables determining fertility (Kaa 1996, p. 403). They were postpartum amenorrhea (the effect of breastfeeding), period of susceptibility for conception, natural fertility patterns by age, and sterilization.

Henry's ideas of natural fertility and of tying fertility control to concious choice became central to the study of fertility transition. These definitions caused some major difficulties for conducting a study which could satisfactorily describe a fertility decline in those terms. This was because natural fertility wasn't any one schedule, but a multitude – each specific to a concrete population. And what's more, it depended on whether it was *consciously decided upon* – not trivial to prove when the subjects are long gone and did not leave a written statement.

Henry also initiated a chain of studies relying on a method now called the classical family reconstitution. The procedure was collecting family events (baptisms, burials and weddings) from historic sources– parish register, household lists, inquisitions, etc. –onto a family reconstitution form, and using these to calculate various statistics. These were average age at marriage, birth interval lengths and completed family size. Also, innovative of Henry's method was the use of individual level data, as this was what the reconstituted families were. The method was subsequently applied in large scale in France, and then elsewhere in Europe (Rosental 1997; Rosental and Mandelbaum 2003).

Later however, the method invented by Henry has found some criticism. Alter and Gutmann bring out some of them in their article "Family Reconstitution as Event-History Analysis" (1993), finding that as the method kept only families with complete fertility histories in the calculations, then it has selection-bias for complete families. The reason for why Henry and followers did this was that with seemingly partial data one could not be sure if the fertility history was really that short, or there was data missing. Discarding these introduced a bias toward families larger in size and sedentary to some geographic location. Alter and Gutmann argued that there are reason to believe that people having these characteristics are not a random sample of the whole population, but could share some set of specific characteristics.

A second critique to the classical family reconstitution analysis is that as it did not use regression type analysis, it was difficult to compare subgroups in the population, and to include the effects of previous life course. The method also lacked meta-measures like standard errors and confidence intervals to assess how trustworthy the calculated results were. The answer to these was event-history analysis, which in addition was readily applicable for reconstituted families. We will say more about the advantages of event-history methods in the "Method" subsection, but will now go on to discuss mechanisms of how fertility became to decline.

2.3 Adjustment or innovation?

One take on the fertility transition has been on the axis of adjustment versus innovation. The innovation hypothesis says that contraceptive methods were not known prior to the transition and their use was what spread and caused the change in fertility – the *want* being already there. The adjustment hypothesis instead states that the techniques of contraception were already known, and that it was change in external conditions that motivated people to start using them in a much larger scale.

It was the Princeton project which brought the innovation hypothesis into the center of discussion (Kaa 1996, p. 420). The project, lead by the Princeton university and formally called the European Fertility Project (1963-1986), was a consolidated effort by scientists from Europe and North-America to use demographic and socioeconomic data from 19th to 20th century "to document the narrative [of the fertility transition] in detail and to provide empirical verification or refutation of specific explanatory hypotheses" (Watkins 1986, p. 422). As data the project used aggregate vital registrations and censuses acquired from over 200 provinces in Europe. The geographic units in the frame of the project were called provinces, which were "smaller than [an] entire country, but larger than a village or the parish" (Watkins 1986, p. 425) and chosen as such to be a balance between being fine-grained, but generalizable.

Keeping in focus the assumption that fertility transition took place within marriage, a set of indices I_f, I_g, I_h and I_m to describe accordingly total fertility, marital fertility, illegitimate fertility and proportion married. The first three I-s are fertility schedule indices standardized to that of the Hutterites in 1930s – an anabaptist sect in the United States, who had the highest ever recorded fertility of a real population. I_m is a simple proportion of women married at childbearing ages (Coale and Treadway 1986). By constraints of the data, these indices were calculated indirectly for the Princeton's study: from sums from vital registrations and distributed to proportions of appropriately aged women found from censuses.[5]

The project found fertility transition to start in the majority of European provinces– with the exception of France –after 1870 when fertility declines were triggered as by a domino effect all over Europe, and by 1930 most provinces had half the fertility they had in the beginning. The main outcome of the project was that the decline in family sizes was only weakly correlated with socioeconomic factors – that is, fertility declined throughout Europe regardless of the socioeconomic, cultural, and infant mortality conditions. Instead, limiting family size seemed to spread mainly within speakers of the same language, and within those regions *time* seemed to be a better predictor of the onset of fertility transition than any other variable (Watkins 1986, p. 441).

The findings of the project raised the question of what was it that was diffused? Was it the practical knowledge of how to use any contraceptive methods, or, instead were the techniques known, but them becoming acceptable that was spread? If the answer is the latter, what were the reasons for controlling one's fertility – were they economic or were they to follow a social norm? Spread of contraceptive techniques could have been an easy answer, but later research found an abundance of cases where controlled fertility was used prior to the onset of fertility transition (see section on spacing below).

With these kinds of results, Ansley Coale postulated three conditions on which every population depended, that created the observed outcome (Coale 1973, p. 65): (1) effective techniques of fertility reduction must be known and available = biological/technical dimension; (2) reduced fertility must be perceived to be advantageous = socio-economic-structural dimension; (3) fertility must be within the calculus of conscious choice = cultural/ideational dimension.These mostly subsumed most if not all theoretical discussions of the mechanics of why fertility declined.

The point of these was that if all three were present, a fertility decline would follow. Otherwise, with any proper subset of the preconditions being true, the

[5]A direct way would have been to use mothers' ages from vital registrations – had these existed in the sources.

outcomes would vary accordingly. For example taking Hutterites at 1930s as a reference group, they had conditions one and probably two present, but condition three was prohibited by religion. Given the time of the situation, United States in 1930s, the outcome was as extreme as it was (Coale 1973, p. 66).

Coale also made a second point in relation to these preconditions: as the presence of these preconditions varies across populations, then no *one* model specification might work for them – each could require its own. Coale cites an example from Ronald Lesthaeghe, who demonstrated that similar multivariate relations between fertility and socioeconomic variables in the communes of Belgium were statistically significant when run separately on the French speaking and on Flemish speaking populations. But when used together, the relationships were weaker or even meaningless (Coale 1973, pp. 64, 67).

At the same time of the Princeton project Gösta Carlsson studied adjustment vs innovation in the case of Sweden (Carlsson 1966). He hypothesized that if innovation was the case, then the following two assertions should be true: (1) effective contraceptives were unknown pre-transitionally, and (2) there was time-lag in the spread of fertility control through social networks – possibly from urban to rural, but other source-destination groups could be specified.

By using variables of urban-rural residency, geographical unit, and transportation networks as variables, he found little evidence in support of the innovation hypothesis. Neither residence type nor transportation connections predicted the emergence of fertility control, because the onset of low fertility didn't start from urban areas and spread into rural areas through transportation connections. He found instead that transitions took place almost simultaneously in both residence types– being slightly faster in the former –and variations between them remained similar throughout. These variations, Carlsson believed, point clearly to pre-transitional fertility control, as cultural differences couldn't have been that large to explain the geographic differences. Thus he concludes that in Sweden adjustment seems the more probable cause of fertility decline.

2.4 Criticism of the Princeton project

The Princeton project has often been criticized because of using measures not really capable of detecting the exact timing of decline nor subgroup differences of the decline.

One of the most thorough criticisms has been "What Do We Know About the Timing of Fertility Transitions in Europe?" by J. Trussell, T. Guinnane and B. Okun (1994). The authors simulate populations, calculate I_g-s and m-s[6] against these, and show how the indices fail to detect a large subpopulation of about 20% to practice stopping behavior. The authors show plausible cases where I_g and m stay relatively constant over time in despite of substantial changes within substructures of the population: e.g a gradual transition from birth spacing to stopping might go entirely unnoticed, because they mask each other's symptoms in I_g (Trussell, Guinnane, and Okun 1994, p. 16).

They conclude that "unfortunately, estimates of I_g and m may mis-date the early stages of fertility transitions, and the bias in the estimated dates may vary from context to context. Because both measures are insensitive to sizable increases in the proportion practicing fertility control, the magnitude of the bias will depend on how rapidly the use of fertility control spread. In the case of I_g, the magnitude of the bias also may depend on the extent to which parity-dependent fertility control is substituted for parity-independent control, or the extent to which changes in breast-feeding behavior accompany the transition" (Trussell, Guinnane, and Okun 1994, p. 17). Therefore Princeton's methods have some of the same drawbacks as the crude rates, where processes internal to the population are not reflected on the aggregate level. This either causes the indices to not notice any (substantial) changes at all, or show them to take place too late, when they were well under way. This is yet another reason to use event-history methods instead.

[6] m, together with M, are Coale-Trussell indices (Trussell and Coale 1974, 1978) which are based on the Henry's data in 1961. M is standardized level of marital fertility at age 20-24 and m is the slope of decline from that to age 45-49. Thus for a given population M would represent the level of natural fertility and m the extent of parity specific control.

2.5 Spacing

Moving on from the insensitiveness critique, there has been another issue brought up regarding the Princeton's indices. There is a growing body of evidence that there is another aspect to fertility control in addition to stopping, namely birth *spacing*.

The fact that other control patterns might exist was known at the time of Princeton project, but with the focus on parity-specificity and also that it was impossible to detect it with the project's data, then no real attention was paid to it, or as been said by van Bavel (with the help of Knodel): "Knodel (1988, pp. 318-9) cites "the greater ease with which deliberate stopping can be detected compared to deliberate spacing" as the single most important reason why historical demographers have focused much more on the former than on the latter form of fertility control."(Bavel 2004a, p. 95)

As it's name says, controlling one's fertility by spacing simply means making the birth intervals longer, with the intent of reducing the "density of births" over the female's life course, or postponing a specific birth due to some contemporary condition. As with stopping, the legitimizing factor here is that of *deliberacy*, that is, spacing must come from conscious choice.[7] Compared to stopping, spacing too, leads to a smaller completed family size. Different from how stopping achieves this, children are had during a longer period of time, hence *spaced*.

The path to this topic's prominence started at the end of the 1980s, when David and Mroz (1989a,b) showed with statistical rigor that at a time where contraceptives were relatively ineffective, spacing was a viable alternative to reduce the amount of dependent children. They found many interesting effects, the first of which was that higher infant mortality increased hazard to next birth – even when controlling for the effect of breastfeeding, which too, when cancelled, leads to a faster next birth. Yet another finding was that of sex preference, where a family of only male children increased the hazard to next birth, while girls didn't. Both of these findings indicate the existence of deliberate fertility control without the criterion of parity.

[7]In fact Henry himself used the notion of spacing in his classic article (1961), but didn't consider it fertility control as he only saw the circumstantial side of it – caused by the same reasons leading to variations in natural fertility (see above).

Yet another argument in support for spacing was put forth by Gigi Santow (1995), who made a case for *coitus interruptus* being known well before the fertility transition. She based her study on abundant citings of the technique in religious and literary writings, court protocols, pamphlets, etc. Confronted with such an elaborate review, it is difficult to doubt the spread of this contraceptive technique among the peoples of Europe.[8]

Indeed, stopping needn't be the only strategy to control fertility, there are quite a few plausible reasons a family could want to space their children. E.g. mothers could devote more attention to any given child; it would make them more available for household tasks, or even for work outside of home; also, a smaller amount of young children would be less of a burden on the family's budget (Bavel 2004a, p. 96). In sum, it is not unreasonable to hypothesize the existence of spacing within historic populations.

As an increasing amount of individual level data are collected, quite a few studies on this have been conducted recently. A number of articles by van Bavel and co-authors (Bavel 2003, 2004a; Bavel and Kok 2004, 2010) has aimed to detect the effect of number of alive children and proportion of dependent children on birth interval lengths, and on both cases found positive results. Parallel with van Bavel, Martin Dribe with co-authors (Bengtsson and Dribe 2006, 2010; Dribe and Scalone 2010) has measured the effect of economic hardships, proxied by grain prices, on birth intervals and has got similarly positive results.

Both of these research groups, while controlling for numerous other factors that make birth intervals longer, have found the strongest reaction in postponed births within subgroups whose economic well-being is tied to the fluctuations of market prices. These are unskilled workers with little or no property, and with no monetary or food buffer, who due to their weak economic stance operate close to the poverty line, and therefore have to be very careful about their fertility behavior – so that they won't have a child in its most vulnerable age at a year of scarcest resources. The studies also make other distinctions, e.g. in the dimension of religion and of other occupational categories, and find positive results, but the greatest effects are

[8]Although the article sets out only to show *coitus interruptus* as widely known, other fertility control methods are mentioned in the sources too (listed in the article), such as abortion and abstinence – both in context of deliberately control fertility.

carried by a population we might call a proletariat. The conclusion of these recent studies are that deliberate fertility control was acceptable and practiced in the lower classes of society, and methods for achieving it were known. Therefore two of the Coale's three conditions– knowledge and acceptability –were present prior, and as we just saw, used when required.

So, a short summary what we know thus far would go as follows: fertility indeed could be controlled prior to the transition. As mortality was still high, parity dependent methods couldn't be employed because one couldn't really stop at any number of children – some of them could possibly die before reaching adulthood. So parents had to "overshoot" (i.e. no stopping), but do it only as much as they could economically manage at the time, and this was the motivation for birth spacing.

2.6 Stopping and spacing in recent studies

In addition to the works conducted within the Princeton project, there have been some more recent studies that look at the fertility transition as a whole.

Violette Hionidou has studied the population on the Greek island of Mykonos (Hionidou 1998) using both quantitative and qualitative methods. In combining interviews with people born in the beginning of 20th century to age-specific fertility rates and birth interval lengths, she proposes a multi-stage passage from natural to controlled fertility (Hionidou 1998, p. 80). There are four stages. In the first, there was no deliberate fertility control. In second, fertility control was perceived advantageous, and spacing through traditional methods, such as longer periods of breastfeeding, became the means. Over time, contraceptives got better and tighter control over spacing was achieved. As also the mortality decreases further, then, as a final stage, stopping was introduced as a complementary strategy to spacing. As stopping is a more decisive way of curbing family size, its presence in crude statistics is more easily observed.

Another study that looks at the fertility transition as a whole has been conducted for the Spanish town of Aranjuez by David Reher and Alberto Sanz-Gimeno (2007). Instead of birth cohorts they use *first* birth cohorts (i.e. mothers having their first birth at the same time) from 1871 to 1950 as the main variable. These maternal cohorts should cover the transition wholly, as the fertility decline for the province was estimated to begin at 1900-1910.

The method used by the authors is to tabulate probabilities of next birth across cohorts by various factors: children born, children alive, child mortality (at age 5), mean ages of first and last births, and birth interval lengths; and in the end propose, too, a multi-stage layout for the fertility transition. It goes as follows: as child mortality fell throughout all the cohorts, so did women start to find ways to control fertility. Initially, stopping became to be the method of choice. This was due to child mortality decreasing, but not yet to a level of being negligible, and thus it was not possible to use spacing predictably.[9] As child mortality decreased further, and in parallel contraceptives improved, then it became increasingly possible to space without the fear of "undershooting". The evidence for this can be seen for how the birth intervals became longer only for the last cohorts (Reher and Sanz-Gimeno 2007, Figure 3). In the end, with low child mortality and near perfect contraceptives, both stopping and spacing were kept in use. In this explanation, spacing and stopping were in reversed order of what Hionidou described.

In addition, Reher and Sanz-Gimeno studied differences between populations occupied in agriculture and in urban types of activities. They find that "all reproductive indicators are lower among women in households with urban occupations: fewer children ever born, fewer children dying, and smaller net family size. While the general time line for change is similar in both occupational contexts, our data suggest that the reduction of fertility began earlier and the increase in completed family size was more attenuated among households with urban rather than rural occupations (Figure 4)."(Reher and Sanz-Gimeno 2007, p. 719) They go on to claim that "ideal family size may well have been lower among urban groups, and fertility limitation may also have been more efficient among them. /.../ Couples in both urban and rural occupations show sensitivity to the number of surviving children, but those in urban occupations always show a greater willingness to cease childbearing at every combination of parity and child survival. With spacing, on the other hand, there are few differences between the two groups. While repro-

[9]The explanation was that it is more secure to generate an overhead and stop, rather than space by always keeping target number of children alive, because after becoming infertile this target can not be reached anymore.

ductive strategies may have been implemented by everyone, they appear to have been more efficiently implemented among those involved in urban occupations. Among urban families there were either greater incentives or a greater ability to limit family size, although the reasons for this are not apparent in the data presented here."(Reher and Sanz-Gimeno 2007, p. 720) To be precise, the authors here looked at urban and rural occupations while in our study we look at urban-rural residency. A comparison is still appropriate because when using residence type as a variable– as we will –then we really don't mean that the proximity of an urban area is itself important, but everything it proxies is, including occupation.

The authors of the paper conclude that in the context of the Spanish town child survivorship was the crucial factor in determining fertility outcomes, and also that ideal family size has always existed in the minds of people even prior to the transition, evidence for this being the family size of 4-5 children for many pre-transitional populations. They also think that fertility control has always been within conscious choice to some extent, both on societal level– as in Hajnal's marriage patterns (see section 3.2.3) –, and similarly so on the individual level – as seen from the current study.

To add to the picture, Van Bavel resurrected the diffusion idea of how stopping became to be used. He used birth cohorts of 1830, 1850, and 1864 in Leuven, Belgium (Bavel 2004b), and finds that in the emergence of stopping, community factors were most important. The study was set up using the proportion of French speaking women living nearby, where the population start displaying fertility control by stopping earlier. The effect was present and statistically significant for the younger cohorts, but not for the oldest. He also controlled for occupational statuses, as this is where the effect on spacing was previously found (Bavel 2003; see above), but finds none on stopping. As such, this gives evidence for the existence of diffusion effects in determining stopping – the main finding reported by the Princeton project. The author concludes that the choice between adjustment and innovation should not be considered mutually exclusive but complementary, as they have both been shown to be present in various contexts.

As we have seen, with the use of individual level data from three context, the interpretations can be relatively different. This also brings back ideas that were not long ago thought to be of minor importance. Although the main pattern of fertility transition is common to all populations, the specifics vary – both in terms of spacing and stopping, as well as in adjustment and innovation. It is likely that different social and geographic contexts are what eventually determine the actual characteristics of a fertility transition. Our study adds another version into the set.

Before moving on to our own analysis, we will summarize the evidence of fertility transition in Estonia relying on previous research that has, in part or in full, looked at this country.

3 Previous evidence of fertility transition in Estonia

3.1 Backdrop

Although the period of interest for the current topic we study belongs to 19th and 20th century, there are three aspects from the more distant past that are useful to know.

First, for the most part of written history the people that obtained a national identity as Estonians in 19th century were the rural, land-cultivating class. The ruling class on the other hand had since the Livonian crusades in 1208-1227 been of German origin. When Russia in the Great Northern War (1700-1721) conquered the Baltics from Sweden, by capitulations[10] the nobility kept ownership of their property (land and people), control over law enforcement, courts, internal politics and administration, and also the state religion continued to be protestant, whereas it was orthodox Christian in rest of Russia. Thus, the Baltics had had a German upper class for a long time and this didn't change after Russia's conquest.

Secondly, the administrative layout of Estonia was up until 1917 not a nation-state, but divided into two provinces, Estonia and Livonia, the first of these consisting of present-day northern Estonia, the latter of southern Estonia and northern Latvia (south-western Latvia was yet another province, Courland). Thus, by beginning of the fertility transition, Estonia had been part of Tsarist Russia for one and a half centuries, had regardless kept its western orientation and was divided into two provinces. In the following text Estonia will mean the Russia's province until 1917 (northern present day Estonia), and the full current territory thereafter.

Third, the period we are studying– from 1845 to 1949 –have substantial historic developments in it, which also bear influence on fertility behavior. The two developments that were probably most crucial were the times of direct battle activity. These were from 1917 to 1920 during the First World War and the War of Independence, and then in 1941 and in 1944 when battles of Second World War

[10] These agreements of surrender were separately made by Estonian, Livonian, Saaremaa's (*Ösel*), and Courland's nobility with the Russian tsar. Indeed, these groups were bargaining for better conditions with both sides of the war.

went through Estonia. We don't study these periods directly, but they had quite probably strong effects in short-term fertility behavior. Such as fertility being low at times of war when men were mobilised and thus separated from their wives, and also by catching up when war was over. The mentioned years were also surrounded by times of "milder" troubles, which could have had some influences too.

The demographic history of Estonia hasn't been exposed to as much research as countries in Western Europe. There are two sources on which we can describe fertility transition in Estonia. The first is research done within the Princeton project, namely from the books "Human Fertility in Russia since the Nineteenth Century" (1979) and "The Decline in Fertility in Europe" (1986). There has also been some work on fertility transition in the beginning of 1990s by Kalev Katus (1994a,b). We will use these sources in the following description of the transition.

3.2 Fertility transition in the context of Russia

The 1979 Princeton's book on Russia looks at the fertility transition in its transformation from the empire as it was before World War I to almost up until the end of Soviet Union. As with all of the project's research, the methodological base is founded on the indices of overall fertility (I_f), marital fertility (I_g), proportion married (I_m) and non-marital fertility (I_h). I_g and I_m are the most important ones to us, as fertility was regulated through these and the effect of non-marital fertility on general fertility was negligible.

The book's main strengths are the vast geographic area it covers, the specification of urban and rural populations, and also of large language groups within the provinces. The weaknesses of the Princeton project have already been discussed, but still, the book gives a good macroscopic description of the transition.

Note that with "Russia" we mean the Russian Empire until 1917, and Soviet Union in the later years. We also acknowledge that there were geographic areas which belonged to Russia at some period of time and didn't in another. The patterns of belonging have been many-fold: in addition to the inter-war independence types of Estonia (or Latvia), there were also parts of Eastern Europe which prior to the end of the Second World War had never been part of Russia, but became under its influence after the war – mostly areas the Russian troops had reached by

1945. But as these details are not directly important to us, then we don't point them out below.

3.2.1 Fertility

In the following, we will summarise the progression of I_g's for the Baltic provinces and observe how these fit into Russia's context. Princeton's indices using which we operate were calculated for the (approximate) years of censuses: 1897, 1922, 1934, 1940, 1959 and 1970; and as said, we have separate data for urban and rural populations.

Beginning with rural areas, at 1897 the Baltic provinces of Estonia, Livonia (and Courland) had an I_g lower than 0.65. No other province within Russia had rural marital fertility that low. What's more, there are only two provinces in the next interval, seven in the following, while the rest of the 38 provinces had I_g above 0.75. By 1926 the situation had not changed, the three Baltics still belonged to the lowest interval of below 0.55 I_g (the following two intervals containing only three provinces and the rest coming after).

By 1940, although the decline of I_g-s had continued, the ranking was different – as the rapid decline in the Baltics had ended and the rest of Russia's western provinces had reached similar fertility levels. The empire was now a two-tier system: all of western Russia, including the Baltics, had a below 0.5 I_g, while the whole of eastern Russia was above that level (Anderson, Coale, and Härm 1979, Map 2.3). By 1959 Estonia was not with the lowest fertility group anymore – St. Petersburg, Moscow with surroundings, and southern Russia had sank even deeper, and by 1970 Estonia among other western provinces had a relatively high I_g as compared to the rest of the Soviet Union.

The urban population shows a similar picture, with the exceptions of metropolitan areas of Moscow and St. Petersburg. At 1897 these two areas were the leading provinces in low marital fertility with I_g below 0.5. The urban populations of Estonia and Livonia had marital fertility only slightly higher, in the interval from 0.5 to 0.55. In all other provinces the urban populations had higher marital fertility. By the year 1926 Estonia (and Latvia, both now independent), and St. Petersburg had the lowest values for urban I_g at 0.35 or less – being in the lead in fertility transition in the territories of former tsarist Russia. But at 1959 many other areas' urban populations had followed their declines into low I_g. By 1970 Russia's western provinces– Baltics, and other provinces in the western front –had the *highest* marital fertility, 0.20 or more, while inner provinces of Russia had declined even further.

When compared to European provinces in Coale and Watkins 1986, the Baltic provinces were in the lead of the fertility decline. The decade for the 10 percent decrease was estimated to occur in the 1880s (Coale and Treadway 1986, p. 39, 1986, Map 2.1). The 10 percent criterium is a relative measure; the absolute values for 1870 I_g was 0.6-0.67 for Estonia and 0.67-0.74 for Livonia. These intervals are comparable to many European areas like the southern provinces of Sweden or Finland, but also to Spain, England and southern Germany. Estonia and Livonia ranked low in European context also in 1900, but by the 1930s many central European states had reached much lower levels of I_g (Coale and Treadway 1986, Map 2.3, Map 2.4).

3.2.2 Effects of nationality and infant mortality rate

Coale, Andersson and Härm (1979) ran several regressions to study the relation between nationality and fertility in Russia provinces. For its provinces they created the following categories: provinces with $> 10\%$ of western type of nationalities, provinces with $> 90\%$ of Great Russians and others, and provinces with $> 10\%$ of eastern type of nationalities.[11]The results were that having a large western (majority or large minority) population in the province had a confirmed negative effect on I_g-s for the years up until 1959. In 1926 the map for provinces with lower I_g essentially coincides with the map for provinces with significant western components.

In addition to national composition, also infant mortality rate (IMR) was used as an independent variable to predict I_g. It turned out that the effect of proportion western and of IMR are almost the same on I_g (only signs reversed) for the

[11]The western type of nationalities were Estonians, Latvians, Poles, Lithuanians, Jewish, Ukranians, White Russians, Western Finns such as Karelians, etc. Note that some of these nationalities lived outside of Russia (or Soviet Union) at some of the times during the period which the book covers. The eastern type of nationalities were Tatars, Bashkirs, Kalmyks, Maris, Komis, Votyaks, Mordvian, etc. See Anderson, Coale, and Härm 1979, p. 68 for more.

years 1897 and 1926 (Anderson, Coale, and Härm 1979, Map 2.11). The authors suspected a common cause for both of these indicators, but it remains unknown.

3.2.3 Nuptiality

We will now look at the marriage patterns within provinces, of proportion married and age at marriage. For this Anderson, Coale, and Härm 1979 used Hajnal's marriage patterns (Hajnal 1965): proportion married, and age at marriage through singulate mean age at marriage (henceforth SMAM; Hajnal 1953). To refresh, the patterns are as follows: Western European: SMAM >= 24, by 20-24 less than 40% married, after age 50 10% remain unmarried; Eastern European (east of the Hajnal's line): SMAM 20-23, by 20-24 more than 60% married, after age 50 less than 5% remain unmarried; Non-European: SMAM < 19, almost all married.

The Russian provinces are compared to these patterns and at 1897 the same distinct clustering emerges (Anderson, Coale, and Härm 1979, Figure 4.5). Rural populations of the provinces fit into the model by dominant national groups: Baltics are within Western European model, Great Russians and many others within Eastern European model, and Eastern nationalities within the non-European model.

What happened after 1897 was that there was a convergence of all three different patterns to "modern" levels: relatively high proportion of marrieds, and a mean age at first marriage around 22-23. The authors explain it as the reflection of balanced fit for populations in modernised countries, where the following conditions predict the outcome: as non-marital sexual relations were not acceptable behavior, but menarche starts well before mid 20s, one would want to get married earlier than second half of 20s; with near perfect contraceptives the couples can now get married without having to be economically ready for children – hence the shift to earlier ages at marriage in Europe.

3.3 Transition at county level

An Estonian demographer, Kalev Katus has looked at the fertility transition at a level lower than the province – in counties (Katus 1994a,b). Methodologically, the study is also based on the Princeton's indices.

Katus used data from censuses in the Baltic provinces of Estonia and Livonia in 1881 and 1897, in the First Estonian Republic in 1922 and 1934, and in Soviet Union in 1959, 1970, 1979 and 1989. The strength of his work is the greater granularity, but unfortunately no urban-rural distinction is made. Still, county level dynamics give valuable insight.

Katus calculated the fertility indices at sub-province levels. He found that within the counties the standard deviations were relatively small, for I_f the difference of lowest and highest is 0.0474 in 1881, 0.0619 in 1897; for I_g same numbers being 0.0825 and 0.0863. Percentage-wise the differences were about 15% at 1881, and 20% in 1897 (Katus 1994b, Figure 11).

The leading counties in low I_g in 1881 were Harju-, Tartu-, and Viljandimaa. Harju and Tartumaa contain the largest towns of Tallinn and Tartu. What stands out though is the equal position of Viljandimaa. It did have a town Viljandi, but this wasn't large at all, nor was the county in any leading position in industrialization, but a mostly rural area, relatively remote from trade routs and external connections. Viljandimaa's leading role is confirmed by the fact that in 1897 this county had broken even further away from Harju- and Tartumaa. At 1922 though, Harjumaa had caught up and surpassed Viljandimaa, and, containing the capital of the country, fell deepest in value by 1934. With no urban-rural distinction, it is unfortunate that we can't say more.

The laggards in the transition are the more remote regions of Saare-, Võru-, Petseri- and Virumaa. Petserimaa, due to its large Russian orthodox population is a clear exception to all the other counties. In addition, Saaremaa (*Ösel*) had the highest fertility rates by 1934, lagging behind in the fertility decline probably due to its remote position as a separate island.

The variance in the fertility indices is highest in 1922, which is the time of fastest decline – the more industrialized counties had already passed through the fastest decline, and laggards were just entering it. By 1934 the spread had come down again, but not yet to pre-war levels.

3.4 Summary

To summarize, in the Russian context the urban populations had an overall lower fertility already in 1897, especially in the big cities of Moscow and St. Petersburg.

Rural populations on the other hand show the full diversity of the empire, with much greater variance in I_g and in marital patterns. With the exception of the Baltics, rural areas of Russia were untouched by fertility decline in 1897. Many of them had started the fall in I_g by 1926, all of them by 1940. Geographically, we see a gradual increase in I_m and decrease of SMAM outward from the Baltics. The transition swept from west to east, starting from the Baltic corner and moving outward to other Western provinces and then inner Russia. Over the course of the transition there is a reduction in the variance and toward a "modern" I_g-I_m arrangement – of low marital fertility and early age at marriage. The nationality impact was great on the change in family behavior. Western nationalities led the transition in 1897, Great Russians followed by 1926 (and were about equal in I_g at that time), eastern nationalities lagged behind.

When discarding state borders and comparing I_g-s on maps with values ranging from 2.2 to 2.5 in the western European analyses (Coale and Treadway 1986), then Estonia and Livonia seem to have belonged to the protestant Baltic Sea region, being relatively early with the start of the fertility transition, but slowing down somewhere after the beginning of 20th century. Additionally, county level evidence suggests that there are some noteworthy differences within the provinces of Estonia and Livonia themselves, some of these could have started fertility declines even earlier than the 1880s.

4 Research question

The purpose of our study is to describe the fertility transition across 19th-20th century birth cohorts by using individual level data from Estonia, look at different paths taken by urban and rural populations, and also inspect the dimension of stopping one's fertility career versus spacing the births. We know that the transition took place within the period for which we have data (1845 to 1949). What we don't know are the specifics of the fertility transition, therefore questions that we plan to have answers for by the end of the study are:

1. what was the timing of the fertility transition in Estonia, and how did different birth parities contribute to the transition?

   We would like to find out which were the cohorts started to control their fertility and whether we can see different stages of the process. Looking at completed family sizes, then on the surface level we know that the change in fertility was toward a one-or-two child norm while an increasingly small fraction of women continued to move on to higher parities. We can do better by not only looking at eventual family size, but at each parity separately – were the reductions parallel, or did higher parities behave differently?

2. how did urban and rural populations differ in regarding to parities?

   The Princeton project's books have already highlighted the urban-rural differences on an aggregate level: we know that the transition started earlier and was more emphasized in the urban context. We would like to know how this distinction plays out in terms of birth cohorts and parities – what were the paths for these subpopulations on their way to lower fertility levels.

3. how did the birth intervals change regarding relative time to next birth?

   Survival models allow us to look at the shape of hazards in relative time after any previous birth, which allows us to look at the spacing dimension. We can search for patterns of peak hazards for any given parity and see if these move to earlier or later durations, and accordingly interpret changes in terms of decreases or increases in birth spacing.

4. how do observed changes fit into theories explaining the reasons and motivations behind the fertility transition?

   In the literature overview we discussed various conceptual frameworks through which the transition has been looked at previously, namely whether fertility was spread as an adaption to some external condition, or was the low fertility behavior a social innovation, i.e. a spread of new norms. Also the issue of spacing was reviewed, and how it had developed in different ways in various contexts. We certainly won't be able to give a definite answer on any of these topics, but we'll try to fit the theories onto what we find.

The variables which will be used to answer these questions are spelled out in the "Model and variables" section.

5 Data and methods

5.1 Data

The dataset to be used in the thesis is based on the family registry of the First Estonian republic. It is similar in structure to present day population registers.

When Estonia became independent in 1918, it parted from Tsarist Russia with no state organized system for keeping track of its population. The closest thing to a population register were parish registers – books kept in virtually every protestant and orthodox parish, wherein baptisms, burials and weddings were registered. Although widely in use, they posed a few problems. First, they were kept by the church, thus not under state control or direct use; also the reasons for having them didn't conform to state requirements. The most practical of these was that in parish registers the events were just noted down, with no references to other events for its participants.

Therefore, to maintain a modern state a system was instituted for the tracking of the state's population, it was called the Family register. A large part of the following account of this register was compiled through personal communication with Allan Puur of Estonian Institute for Population Studies.

The Family register was created by a law enacted on November 12, 1925, which went into force at July 1, 1926 (*Riigi Teataja* 1925, p. 110). It described the format of data to be recorded, who it should be recorded by, and when.

The burden of maintaining the register was put upon the local governments of cities (*linn*), towns (*alev*) and boroughs (*vald*). A supervising institution (*Perekonnaseisuarhiiv*, "Family stance archive") was founded in Ministry of Interior (*Siseministeerium*). This institution was responsible for the archival of the documents, and also for developing principles and procedures, counseling local officials, auditing, and coordination with other ministries (*Siseministri juhtnöörid perekonnaseisu seaduse kohta* 1937).

Registering one's family related events was compulsory to everyone.

The major difference from parish registers was that it kept records that effectively kept all events pertaining to one person in a separate page. That is, every record kept both vertical (parent-child) and horizontal (spouse) relations of central person.

When the person moved, (s)he had to register it. Automatic movement of records took place only at time of marriage. When the wife's original record was closed, copy was sent to the husbands locality, and the wife's information was added to the husbands record. Records were also closed on the person's death and some other occasions (*Perekonnaseisuametniku käsiraamat* 1939).

As the effort required by both the population and state officials of registering the whole of population at the time when the institution was created, a system was invented to do it over a period of time. Records were opened at time of marriage, spouses death or birth of a child. Stillbirths were also recorded. When there were unrecorded events from the past that belonged to the current record, then these were added. Only when the first event for an unmarried person was death, then no record was created.

Forced into a role model, the registrants themselves had to open their own records by January 1, 1935. The rest of the population had to be registered by January 1, 1939. In 1938 the deadline was extended by one year.

The recording of people was close to including the whole of the population by beginning of World War II. Although Soviet government planned to integrate its own system then the current one was temporarily continued, and thus we see registrations throughout the war, after which the number of events gradually declines. The register was officially closed at March 1, 1949 (*ENSV Teataja* 1949). At 1957 the records were ordered to be archived at city and county governments, where they remain until today.

The advantages of this data source are that it is a relatively full snapshot of people living in Estonia at and before the First Republic. Due to compulsory registration then those who registered also included their parents, and therefore we have birth-dates that go back to the middle of 19th century. But as the registration for the older generation, who didn't survive until the register was opened, is conditional to them having children, then will use only intervals after first birth in the study – see more in section "Model and variables" below. Another advantage is that the data is individually linked: the events pertaining to any one person are on one record. If this was closed after a move or marriage, it links to the record where the events continue; and lastly, the dating is precise by day.

There are also issues in the data that we don't address, but which we will mention here. Namely, during independence Estonia had a little above 10% of foreign nationals. The second largest group of these were Germans with 1.5% of the population at 1934 (the first were Russians with 8.2%). As by the Baltics were left to the Soviets by Molotov-Ribbentrop Pact, then in 1939 Hitler called these Germans back to Germany. It is estimated that about 13 thousand went – of the 16 thousand that Estonia had (Zetterberg 2009, pp. 400-401). We assume in the thesis– and this is quite probable –that the records for these individuals were closed in the register, and are thus correctly censored in the analysis. But prior to that time point the German minority is part of the whole population that we use for analysis, but is not statistically controlled for.

Secondly, we know that the Baltic nobility tended to lived more in urban areas rather than rural, e.g. there were 4.8% of them in Tallinn. It can be argued that this group behaved slightly differently than the general population, probably being relatively more educated and well off than the rest. Did the these characteristics cause different behavior in fertility is unknown. Therefore, though it is possible that this population creates some bias in the analysis then we think that in terms of regression coefficients the change is minor.

5.2 Method

To answer our research questions, we are going to use event-history analysis.

Event-history analysis, also known as survival analysis, is a powerful (and convenient) way to model processes that have a time dimension and a set of variables having different values over that time. The methodology is a generalization of classical demographic methods of life-tables, standardization and multivariate regression (Hoem 1993).

When we discussed the Princeton's indices before, and their shortcomings (not accounting for changes in inner structure and precise detection of timing), then event-history methods solve most of these. The only drawback is that they have much higher data requirements, i.e. to measure the effect of some property then one would need a variable to indicate it. Another advantage (that, too, comes with the data requirement drawback) is that incomplete data can be used in the analysis,[12] given that the process times are correctly censored (Alter and Gutmann 1993).

This is why event-history methods have been used in many demographic studies, in articles, but also in large collaborative projects such as the Eurasia Population and Family History Project (Lee, Bengtsson, and Alter 2004, 2010). These references also demonstrate how great of an influence the data requirements are, as the regions under study are relatively small compared to the area covered by the Princeton project. On the other hand, the results are of much greater detail and allow us to measure associations on the individual level, which get us closer to answering questions on deliberacy in childbearing behavior.

This is why we are going to use event-history analysis in this thesis.

5.3 Model and variables

The specific version of survival model we will be using is the piece-wise constant survival model. The piece-wise constants being there to allow us to bring out the relative shape of the hazard curve for every birth interval.[13] Birth intervals are divided into the piece-wise constant spells at 3, 6 . . . 120 months after birth. We expect the hazard ratios for the constants to have a left-skewed distribution, where the piece-wise constant hazards rise to some peak for the first few years after birth and level out slower on the tail end. We also expect that for a natural fertility population the distribution to be less skewed than a family-planning population. In the former the hazard curve should represent the distribution of fecundity among women and should therefore have a more bell-curved shape, while a fertility controlling population should have a more distinct peak – in a way, putting the "plan" into family planning.

In addition to the piece-wise constants we will use the variable urban-rural residency. This is a dummy variable for urban or rural, derived from where the locus of registration for the mother ended up in by 1949 – and is hence a time-constant value. The use of this, rather than something time varying is purely a

[12] That is, individuals are not required to have completed the process we are studying – a person need not die when modeling mortality, or complete her fertility career when modeling fertility.

[13] We make specific use of these in the plots of section 6.4 and in Appendix figures 17-32.

feasibility issue, as (for example) the birth places of children of a given mother would certainly track her movements more accurately than a constant value taken at where the registration card record ended up in.[14]

As the value of urban-rural residency is taken only from one time point, then it is a proxy of where the subject actually lived. The implication of creating the variable in this way is that the mothers who changed their residence type any number of times are taken as living in the last residence type. As the clear trend since the end of 19th century was of urbanization, and movement in the opposite direction was negligible, then we can assume that part of the urban population was actually born rural.

How this affects our results is difficult to say. Our assumption is that most mothers didn't behave "rurally" while living in a rural area– supposedly, having a relatively larger number of children –and then moved to towns; more plausibly, they migrated before even starting their fertility careers, or relatively early on, and then had children. Given this, then when discussing the urban population we mean the people who ended up in towns, rather than the people who were born there.

The basis for the urban-rural dummy are the town categories enacted by the "Town Law" of 1938 (*Linnaseadus*, *Riigi Teataja* 1938). First and second class towns were coded as urban, third class towns and boroughs were coded rural – the latter because third class towns were relatively small and behaved similarly to boroughs.

The third variable we will use is birth cohort. Therefore we are taking the cohort (rather than the period) perspective for the change in fertility behavior. The advantage that real birth cohorts give us is that they don't suffer from age-pattern changes in marital fertility, and also express experience related to actual rather than synthetic population subgroups (Preston, Heuveline, and Guillot 2001, p. 102). The cohorts are 7 and 19 years in length, starting from the year 1845 and ending in 1919 (the last intervals are cut short at that year).[15] 7-year cohorts

[14] There actually was a text field for each birth in the dataset which stated the location of birth for the given child. But unfortunately these values were raw and therefore not directly usable without a substantial amount of additional work.

[15] The lengths of the intervals were chosen on grounds of practicality – a compromise of granularity and ease of interpretation (and of visualizing).

are 1845-1852, 1852-1859, 1859-1866, 1866-1873, 1873-1880, 1880-1887, 1887-1894, 1894-1901, 1901-1908, 1908-1915, and 1915-1919; and for 19 years: 1845-1864, 1864-1883, and 1902-1919. All individuals are censored at 1949.

Although we have data for both married and unmarried women, the models will use only children conceived within marriages. We do this for two reasons: during the time we have data for only a minority of children were conceived out of wedlock (less than 10% for most of the cohorts, see descriptive tables), and secondly, it is possible that populations differing in this regard (having a child in or outside of marriage) are based differently on normative grounds and can therefore interfere with each other in a single estimation equation. As we have enough cases we can drop the illegitimate births.

We also use only birth-to-birth intervals. The reason to study intervals starting from first birth (and not from marriage or some age) is due to how the data we are using was created. For the oldest cohorts the main condition for them to be in the data is that their children survived to the time when the Family registry was being kept. Therefore those with no children are much less probable in ending up in the registry, leaving the amount of childless individuals underrepresented. Another aspect– had we the data on for the childless too –is that as the mechanism from marriage (or some age) to first birth is different: a conception can *cause* a marriage, rather than the marriage being a precondition to the conception, therefore this interval is not directly comparable to the others.[16]

All birth intervals– open and closed –for a given parity are included and therefore what is measured is the probability of progression to next birth.

All of the models are set up as follows: the data is used as single-event processes for each birth interval. Each episode starts with a birth and possibly ends with a conception. After conception the subjects are not under risk until the birth occurs – time being pregnant is not included in the process time.

As the times for conceptions are calculated by subtracting nine months from the births they lead to, they are conditional to the birth following it. Thus we don't have information on conceptions that were not followed by a birth, although such conceptions quite probably took place. But as we are studying fertility, i.e.

[16]It is part of the fertility transition though, as childlessness increases too during it – we just chose not to model it in the current thesis.

children born, then this is exactly what we want.

When estimating and interpreting the models it is important to keep in mind that each model for every parity is conditional to the woman reaching the previous parity. E.g the population included in a model of progression to parity 6-7 will have had at least had 5 or 6 children. Therefore a reduction in hazards for any parity means a smaller initial population for the next. Therefore for each parity there will be an increasingly select population at risk.

6 Results

6.1 Descriptives

Before moving on to analysing estimation results, let's look at the population in the study by tabulating the data on the variables we have. We will first inspect these and then move on to event-history analysis. Table 1 on mean completed family size is displayed at the end of this section; others, on completed family size for those not childless (Table 3), mean ages at birth parities (Table 4), childlessness (Table 5), number and proportion of births by urban-rural residency (Table 6), number and proportion of births by marital status (Table 7), are displayed in section A.1 in Appendix.

To start, from tables on completed family size (Table 1 and Table 3) we see that the cohorts we have were the ones going through the fertility transition, as stopping moves to increasingly early parities: the oldest birth cohorts have about four children on average, while the youngest at or below two children. For the whole population, replacement level fertility is reached by the 1894-1901 birth cohort – women at prime fertile ages during the 1920s and 1930s. We will later look closer into the structure of how fertility declined, but the reduction of fertility to modern levels comes out well.

Secondly, from the same tables (Table 1 and Table 3) on completed family sizes we can observe changes in child mortality and how it reduces over time – i.e. in how the number of children born converges with children who remain alive. This trend seems to start at 1866-1873 birth cohort and continue to the end of the observed period. Interestingly enough initial child mortality is higher for the urban population, but the rank order turns around at 1873-1880 birth cohort and remains that way. We will return to the decrease in child mortality in the conclusion and look at how it fits with the fertility decline, and could there be any relation.

In other tables we see more trends that are to be expected from a western population born a hundred to hundred and fifty years back: more children are born to rural mothers than to urban due to the household economics being different; childlessness increases over time and it is constantly higher for the urban population; age at last birth becomes constantly lower due to the last parity itself becoming lower; the proportion of births in towns and cities increases due to urbanization, although families itself become to be smaller and even more so in the urban areas; and also, the proportion of non-marital births increases due to social norms becoming to be more lenient.

It is important to note that as the tabulations do not control for age, then some of them become increasingly biased for the three last birth cohorts, as by 1949, when our data ends, they have not finished their fertility careers. For example in the tables the women in cohorts 1901-1908, 1908-1915, and 1915-1919 are in 1949 at ages 41-48, 34-41, and 27-34 respectively. Clearly, there are many women in the last two groups who have not stopped their childbearing at these ages, and thus have a bias toward early child-bearers. The effect is especially visible in the tables on childlessness and mean age at birth parity; other tables are somewhat less affected. The biased cohorts are marked with a dagger (†).

Event-history methods allow us avoid these problems by controlling for age and also allow to include other variables. In the next section we will start with the simplest model and following sections introduce interactions that will bring out both the effect of residence type and also the effect of duration since last birth.

In each section we plot hazard ratios in the main text. We report the estimation results for the first basic model in the main text, but as tables become increasingly large due to the combinations of interactions then subsequent models are reported in section A.2 in Appendix. Estimation results are annotated throughout E1 to E4, and derived figures reference them.

Table 1: Mean number of children born, children alive, and percentage of children dead for Estonian women by birth cohorts from 1845 to 1919

cohort	children born			children alive			children dead (%)		
	urban	rural	both	urban	rural	both	urban	rural	both
1845-1852	3.8	4.0	3.9	2.7	2.8	2.8	30	29	29
1852-1859	3.9	4.2	4.1	2.5	3.0	2.9	34	28	29
1859-1866	3.3	4.0	3.9	2.3	2.9	2.8	30	27	28
1866-1873	3.4	3.9	3.8	2.5	2.9	2.8	28	26	26
1873-1880	3.0	3.8	3.5	2.3	2.9	2.7	22	24	23
1880-1887	2.5	3.5	3.1	2.0	2.7	2.5	19	22	21
1887-1894	2.2	2.8	2.6	1.9	2.3	2.2	14	16	15
1894-1901	2.0	2.6	2.4	1.7	2.3	2.1	10	13	12
1901-1908†	1.7	2.3	2.1	1.6	2.1	1.9	6	9	8
1908-1915†	1.6	1.9	1.8	1.5	1.7	1.7	5	7	7
1915-1919†	1.4	1.4	1.4	1.3	1.3	1.3	4	6	5

6.2 Initial piece-wise constant model

We will now run our first set of regressions: a separate survival model for each parity including all variables as is. Estimation results are displayed below (Table 2), and based on these results we plot the hazard ratios of birth cohorts by parity in figures 1-4, 1880-1887 cohort is used as the reference group.

Looking at hazard ratios for birth cohorts to outline the timing of the fertility transition we see that there is no specific parity which produces it. Rather, the move toward a lower hazard to next birth is evident in all parities from 2 to 7. Note that for parities 6-7 the confidence intervals become larger at for the last cohorts.

By comparing separate parities, the rapid fertility decline starts one birth cohort earlier for parities 3, 4-5 and 6-7, than for parity 2. Therefore it seems that the parity for stopping (i.e. the desired number of children) decreased over time. But there is more to this time pattern: the 1873-1880 had their 4-5th and 6-7th children closer in calendar time to the 1880-1887 birth cohort having their 3rd child, than is the 7-year difference between the cohorts. This means that the period effect was even greater than the reductions we see for the birth cohorts.

Urban-rural residency as a dummy variable shows that the effect of living in an urban area results in a 10 to 20 percent decrease depending on the parity, all ratios are highly significant. As the magnitude is highest for progression to third child then we might suspect this to be the dividing point of fertility aspirations of urban and rural populations.

As predicted, the hazards across piece-wise constants are of a left biased shape: being relatively low until 3 months, then rising to a peak at 12-24 months after birth and gradually declining thereafter, the peak moving from 12-18 months for parity 2 to 18-24 months in the following intervals.

In sum, from the cohort and parity dimensions it is evident that stopping increased at all parities, because less people in each case moved on to have the next child.[17] The start of the decline was earliest for higher parities, and later parity 2 joined in. Urban residency had a strong negative effect on hazard ratios for all parities. We can say more about urban-rural residency in the next section, where the variable is included as an interaction variable rather than a dummy.

[17] See also the Kaplan-Meier survival curves in figures 13-16 below of how stopping increased over birth cohorts.

Table 2: Initial survival models for each parity (or parity-pair) using piece-wise constant durations after birth, cohort, urban-rural residency and mother's age-group as categorical variables (E1)

	parity 2	parity 3	parities 4 and 5	parities 6 and 7
_t				
0-3 months	0.01***	0.01***	0.00***	0.01***
3-6 months	0.48***	0.29***	0.19***	0.23***
6-12 months	0.92*	0.57***	0.38***	0.39***
12-18 months	1.12**	1.00	0.73***	0.80***
18-24 months	1.00	1.00	1.00	1.00
24-30 months	0.91	0.98	0.88**	0.98
30-36 months	0.70***	0.66***	0.59***	0.74***
36-48 months	0.60***	0.54***	0.53***	0.47***
48-72 months	0.39***	0.40***	0.32***	0.27***
72-120 months	0.20***	0.19***	0.12***	0.08***
120-1000 months	0.03***	0.02***	0.01***	0.00***
1845-1852	1.15*	1.26**	1.34***	1.40***
1852-1859	1.12*	1.38***	1.40***	1.44***
1859-1866	1.25***	1.40***	1.34***	1.34***
1866-1873	1.16***	1.34***	1.34***	1.38***
1873-1880	1.17***	1.21***	1.11*	1.08
1880-1887	1.00	1.00	1.00	1.00
1887-1894	0.78***	0.83**	0.81***	0.85
1894-1901	0.70***	0.71***	0.80***	0.96
1901-1908	0.60***	0.60***	0.61***	0.82
1908-1915	0.57***	0.52***	0.67***	0.78
1915-1919	0.46***	0.41***	0.56***	0.53
rural	1.00	1.00	1.00	1.00
urban	0.87***	0.80***	0.83***	0.89*
15-20	1.10*	1.54**	1.05	
20-25	1.00	1.00	1.00	1.00
25-30	0.81***	0.76***	0.75***	0.64
30-35	0.60***	0.51***	0.52***	0.44*
35-40	0.40***	0.34***	0.28***	0.25***
40-45	0.11***	0.09***	0.09***	0.07***
45-50	0.00	0.00	0.00	0.01***
Observations	70067	61930	76737	34673

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure 1: Hazard ratios on transition to parity 2 across birth cohorts. Estonian women born in 1845-1919, risk relative to 1880-1887 cohort (E1).

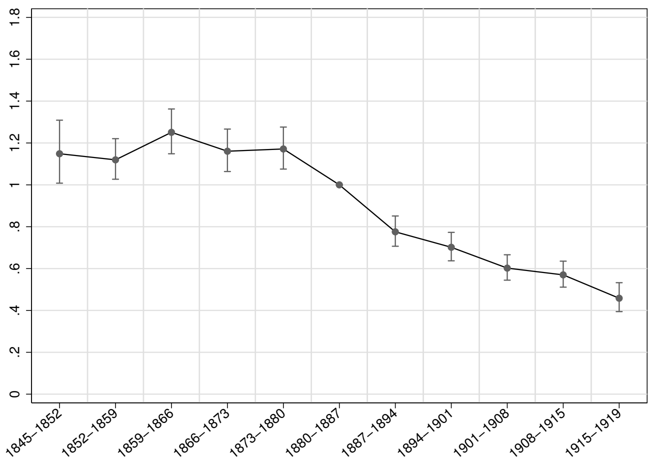


Figure 2: Hazard ratios on transition to parity 3 across birth cohorts. Estonian women born in 1845-1919, risk relative to 1880-1887 cohort (E1).

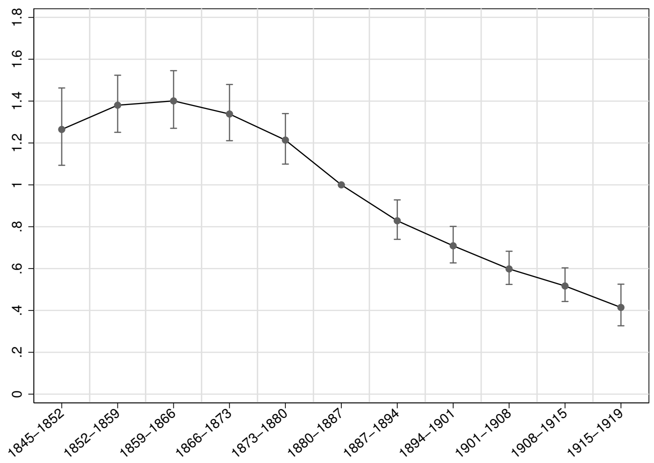


Figure 3: Hazard ratios on transition to parities 4 and 5 across birth cohorts. Estonian women born in 1845-1919, risk relative to 1880-1887 cohort (E1).

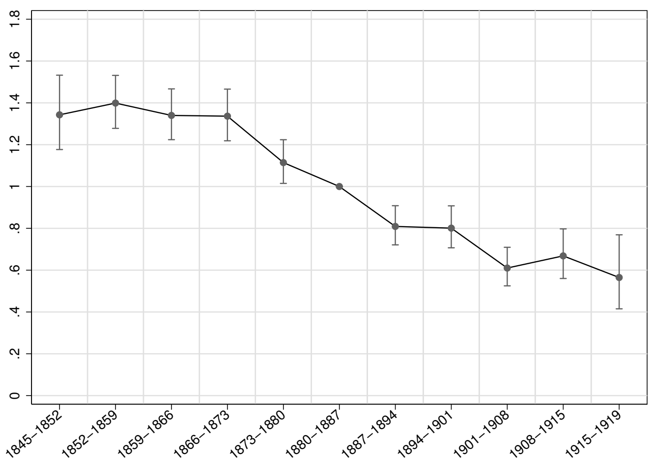
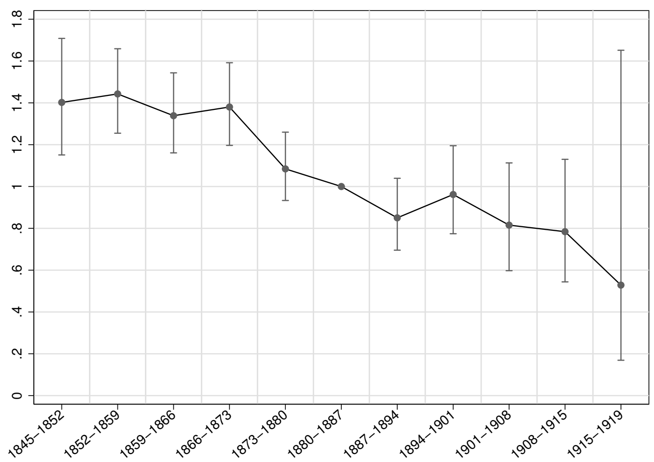


Figure 4: Hazard ratios on transition to parities 6 and 7 across birth cohorts. Estonian women born in 1845-1919, risk relative to 1880-1887 cohort (E1).



6.3 Interaction between urban-rural residency and cohort

We will now look at paths of progression toward 2-7th parity by running models with an interaction between urban-rural residency and birth cohort. We do this to allow the hazards of the urban and rural populations to move freely across birth cohorts and therefore (possibly) bring out the separate paths taken by them. See the plotted hazard ratios below (figures 5-8). Estimation results on which these figures are based on are in Table 8. Note that for the plots on parities 4-5 and 6-7 we didn't include estimates for the last birth cohorts as the confidence intervals became extremely large. The 1880-1887 rural birth cohort was specified as the reference group.

What we find is that for parities 2 and 3 (figures 5 and 6) the hazards for the urban population are initially higher, or, at least equal to that of the rural population. We can't be entirely sure because in all cases where the mean of the hazard ratio is higher for the urban population there do the confidence intervals overlap. Still, them being higher in reality seems somewhat more probable due to how consistently the means of urban populations lie above the rural.

On the parity 2 plot (figure 5), for both residence types there seems to be a steady state lasting until about cohort 1873-1880. Thereafter, the urban population enters a rapid decline during two cohorts, during which passes the rural population, and then slows down for another two cohorts, becoming to a stop at cohort 1901-1908. For the rural population the decline starts at the same cohort, but is slower.

With progressing toward third birth (figure 6) we can't really make out a stability state for the urban population, as the hazards seem to gradually decline throughout all cohorts, possibly hinting to an even earlier start. What we can say though is that, again, the initial hazards are higher or about equal for the urban population, and that the decline for it is faster and reaches lower levels in the end.

Parities 4-5 and 6-7 (figures 7 and 8) display a more fluctuating path. The plateaus we reported in the previous model are clear for the urban population, lasting until 1866-1873 birth cohort followed by a rapid decline. Rural populations on the other hand show a gradual decline, having only a slightly faster movement for the cohort 1887-1894.

In conclusion, the paths taken by urban and rural populations were different. Fertility behavior for the urban population was more pronounced in switching to a low fertility behavior while rural population moved in a gradual manner, where plateaus are less visible. This is similar to the difference of what Reher and Sanz-Gimeno (2007) found for urban and rural populations in Aranjuez, Spain: a simultaneous reduction in fertility for both populations, but where the decline in urban occupations was more attenuated – possibly hinting at on average lower desired family size and more efficient contraceptives.

Next we will move on to the issue of spacing.

Figure 5: Hazard ratios on transition to parity 2 across birth cohorts by urban-rural residency. Estonian women born in 1845-1919, risk relative to 1880-1887 rural cohort (E2).

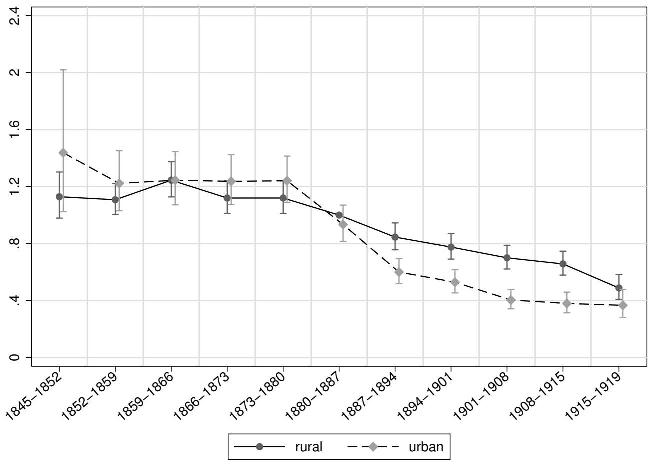


Figure 6: Hazard ratios on transition to parity 3 across birth cohorts by urban-rural residency. Estonian women born in 1845-1919, risk relative to 1880-1887 rural cohort (E2).

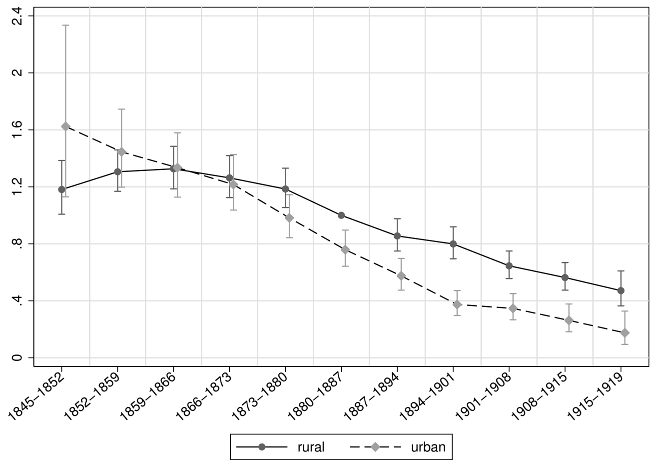


Figure 7: Hazard ratios on transition to parities 4 and 5 across birth cohorts by urban-rural residency. Estonian women born in 1845-1919, risk relative to 1880-1887 rural cohort (E2).

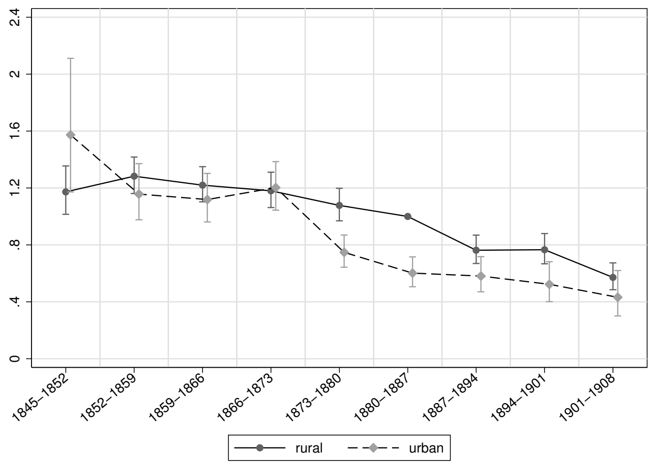
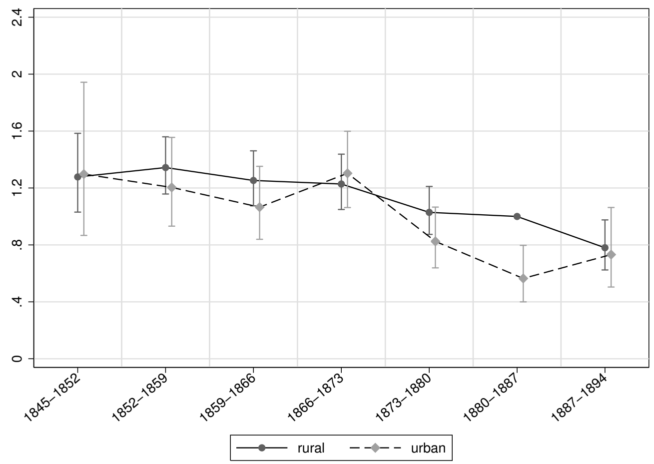


Figure 8: Hazard ratios on transition to parities 6 and 7 across birth cohorts by urban-rural residency. Estonian women born in 1845-1919, risk relative to 1880-1887 rural cohort (E2).



6.4 Interaction between cohort and duration since last birth

Finally we run a set of models with interaction between birth cohort and duration since last birth to look at how hazards change over relative time after birth. This allows us to observe changes in the length of birth intervals – i.e. in spacing. Here we will use four 19-year cohorts, because the previous and more granular approach added little detail, but was much harder to plot and interpret. Also, different from previous is that, to add another view to the spacing-stopping issue, we will plot Kaplan-Meier survival curves for each parity (in addition to the hazard ratios over duration since last birth). See below for the plots and again note the omittance of the later duration-since-last-birth values for higher parities due to large confidence intervals.

We will first go over the general patterns and then look at spacing. We will mostly use the hazard ratios at durations since last birth for the interpretations (figures 9, 11, 13, and 15), as these include the effect of control variables, while the Kaplan-Meier survival curves are simple representations of the life tables without controls for other variables.

Over all the parities we see is that very few children are conceived before 3 months after a birth. This is due the majority of women being temporarily infecund when breastfeeding, but become increasingly less so over time.

The bulk of the hazard for all cohorts and parities lies between 6 to 48 months since last birth, peak hazards sliding from 18-24 months to one or two steps further as parities increase.

As models in the previous sections predicted, the dominant pattern we can observe for the hazard curves is that every younger cohort has significantly lower hazard to next birth than the one that came before. We can see this from how the area for each younger cohort gets smaller. The greatest change happened between the middle cohorts of 1864-1883 and 1883-1902, but the reduction of hazards for subsequent cohort pairs is ubiquitous. The smaller proportion of those not progressing to next birth is also easily identifiable from the survival curves (figures 13-16) which display the same pattern: the middle cohorts have the largest gap between the eventual survivorships, but the decrease in having the next child is evident for all subsequent cohort pairs. All this means that stopping increased throughout all the cohorts.

If looking for similarities, then the two older cohorts, 1845-1864 and 1864-1883 are the closest to each other. These two provide the only statistically significant exception to the rule of always decreasing hazards for every younger cohort: the cohort of 1864-1883 is quicker to have the second child than the cohort preceding it (figure 9). The decrease in spacing for the older two cohorts at parity 2 is also evident on the according survival graph (figure 13), where slightly faster progression to second birth of the 1864-1883 cohort can be seen.

Continuing to inspecting the movements of peak hazards, we can say that for parities 2 and 3 there is a decrease in spacing across all the birth cohorts, as the topmost hazards for both parities move to an increasingly early time since last birth. For example for progression to parity 2 in figure 9 the peak values for the hazards across cohorts is an almost perfect sequence from 18-24 months to 6-12 months from cohort 1845-1864 to cohort 1902-1919. A similar move to an earlier peak can be observed for other parities as well, though the pattern is somewhat less evident for the parity 6-7 model, where also the confidence intervals have become to overlap.[18]

Therefore, in addressing the issue of spacing, I think we can say that the expectation that the hazard curve becoming more left biased for the younger cohorts is true, and that there seems to have been a general trend toward an on-average shorter birth intervals. In comparison to Mykonos (Hionidou 1998) and to Aranjuez (Reher and Sanz-Gimeno 2007), then in Estonia the birth intervals became shorter over time, rather than remaining relatively similar throughout, as in these two other cases.[19]

In addition, we also ran a fourth set of models to tease out any differences spacing-wise between the urban and rural populations. We did this by interacting three variables: cohort, urban-rural residency and duration since last birth. But as we can see from figures 17-32 in our Appendix, they do not add anything that

[18]Note that that the low piece-wise constant values for the younger cohorts seem small only in comparison to the older. Were they to be stretched out over the y-axis (thus becoming not proportional to each other), the movement of the bulk hazard area to an earlier time can be seen more easily.

[19]Note that the methods for measuring were not identical, and also that both Mykonos and Aranjuez were small localities.

we haven't already observed from the current and previous sets of models: there is a similar decrease in birth spacing for both urban and rural populations; and also, the parity-ubiquitous decline can bee seen clearly, including the flip of ranking at parities 2 and 3 between the urban and rural subpopulations that we saw from figures 5 and 6.

Figure 9: Hazard ratios by birth cohorts at piece-wise constant durations after birth on transition to parity 2. Estonian women born in 1845-1919, risk relative to 1845-1864 cohort at 18-24 months after birth (E3).

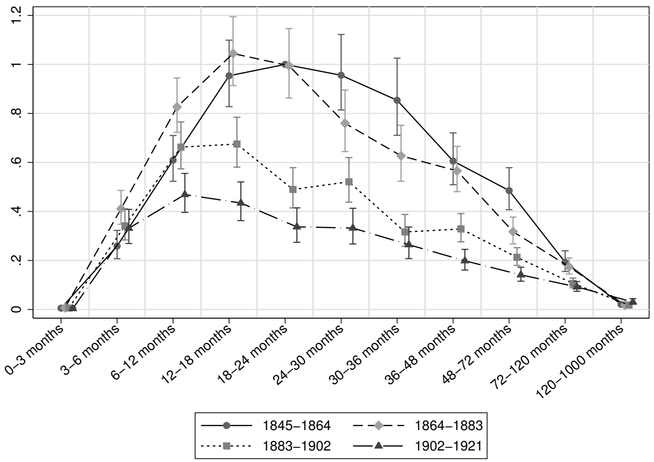


Figure 10: Hazard ratios by birth cohorts at piece-wise constant durations after birth on transition to parity 3. Estonian women born in 1845-1919, risk relative to 1845-1864 cohort at 18-24 months after birth (E3).

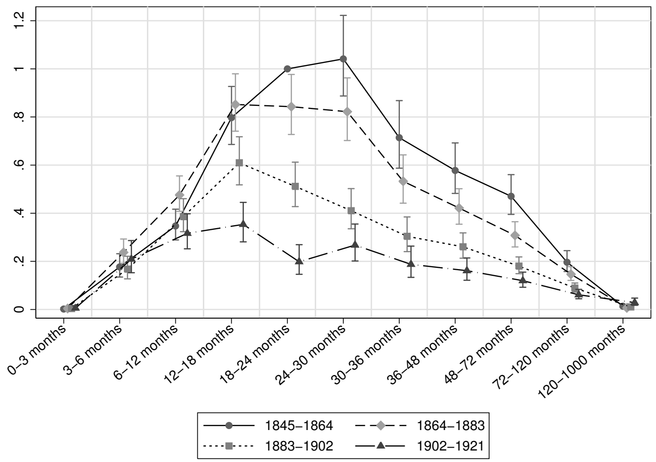


Figure 11: Hazard ratios by birth cohorts at piece-wise constant durations after birth on transition to parities 4-5. Estonian women born in 1845-1919, risk relative to 1845-1864 cohort at 18-24 months after birth (E3).

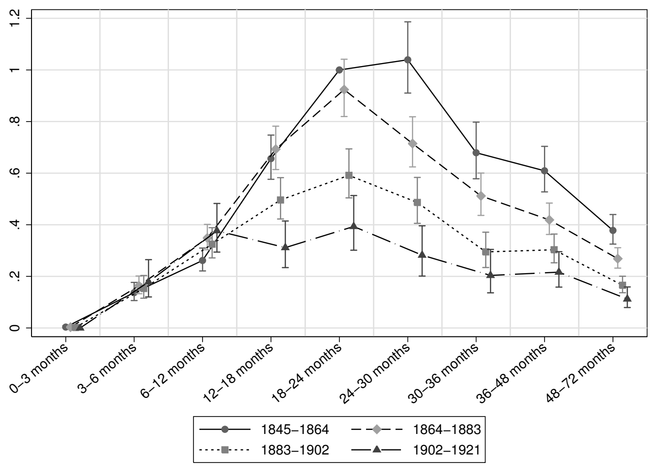


Figure 12: Hazard ratios by birth cohorts at piece-wise constant durations after birth on transition to parities 6-7. Estonian women born in 1845-1919, risk relative to 1845-1864 cohort at 18-24 months after birth (E3).

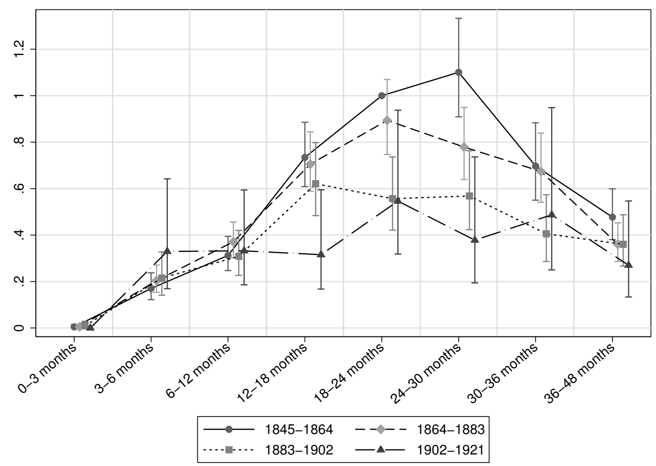


Figure 13: Kaplan-Meier survival curves on transition to parity 2. Estonian women born in 1845-1919 by birth cohorts.

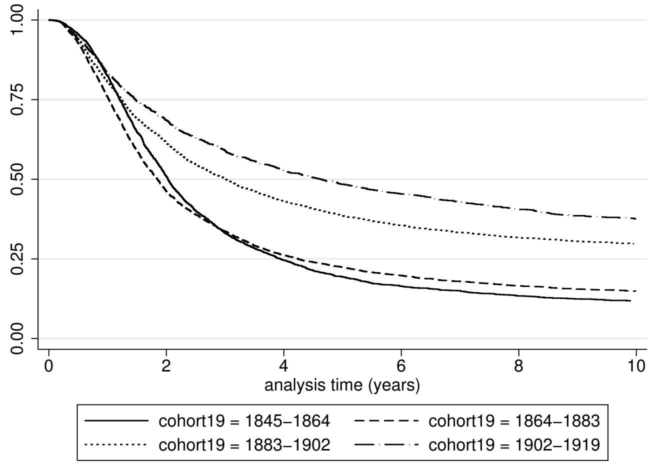


Figure 14: Kaplan-Meier survival curves on transition to parity 3. Estonian women born in 1845-1919 by birth cohorts.

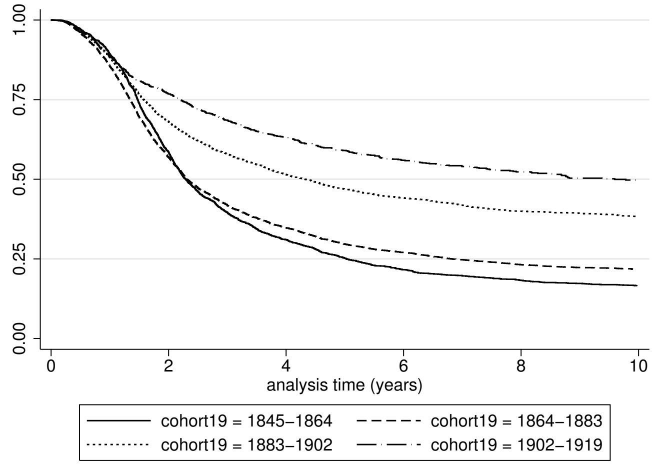


Figure 15: Kaplan-Meier survival curves on transition to parities 4 and 5. Estonian women born in 1845-1919 by birth cohorts.

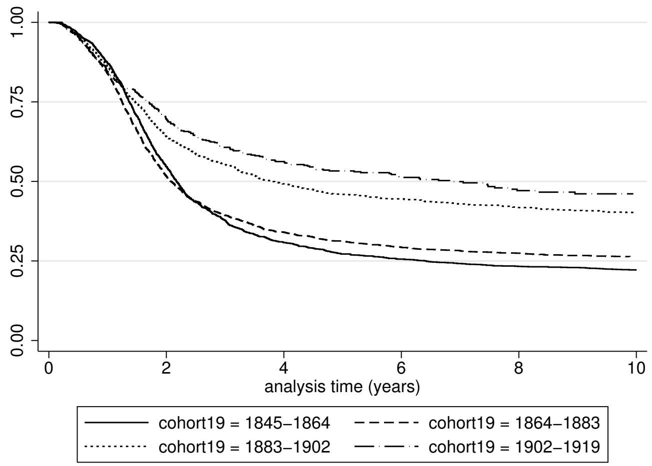
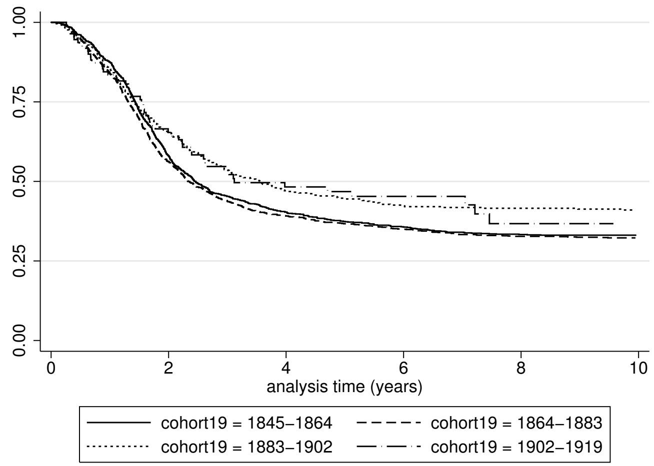


Figure 16: Kaplan-Meier survival curves on transition to parities 6 and 7. Estonian women born in 1845-1919 by birth cohorts.



7 Conclusion

First let us address the descriptive part of the research questions.

On the question of (1) timing of the fertility transition we can say that all parities participated in the fertility decline and the higher the parity, the earlier did the decline start. For parities 3-7 this was at 1873-1880 birth cohort, for parity 2 at 1880-1887. Therefore there is a progression toward an earlier parity for stopping one's fertility career in the cohorts. As higher parity children were conceived at a relatively later age on average, then the effects of these declines piled up to a larger period effect, which took place somewhere around the turn of the century. As we currently took the cohort approach, then we don't know exactly when, but the Princeton's results are probably a close indication. (2) The contribution of the urban population started earlier and was more emphasized, while a milder form of the transition happened to the rural population. Also, as the parity models work cumulatively (a decline at progressing to parity 2 means a smaller initial population for progressing to parity 3), then in absolute numbers the lower parities contributed the most to the reduction on sizes of the following generations. On the third research question (3), from the cohort and time since last birth interaction, we see a decrease in spacing, and this trend is similar for all parities and both the urban and rural residence types. In sum, the female fertility career's shortened both because of earlier ages at stopping and also because the average birth intervals became shorter.

How does the fertility decline as currently analysed stand in terms of the main debates about why and how fertility declined? Lets first take the dimension of adaption and innovation. In the descriptive findings (in Table 1 and Table 3) we saw that child survivorship started converging– i.e. mortality decreasing –at the 1866-1873 birth cohort. In the event-history analysis of fertility we saw a similar decline in fertility starting at the cohort after (in parities 3 upward). As these two processes are in relatively close distance to each other (and also in the right order) it seems at least likely that the declining mortality was what triggered the fertility transition. Given that we used real cohorts (as opposed to synthetic) then the mechanism could be that women were making their new and different decisions by observing the experiences of previous cohorts. The relation seems even a bit more possible when looking at how mortality is slightly higher in the urban population for earlier cohorts (see percentages of "children dead" in the tables) – similar to how urban fertility was initially higher than rural (see figures 5-7). Note, that we can't exclude the possibility of coincidence as the confidence intervals overlap.

Attributing mortality decline as *the* cause to the decline in fertility was the main proposition in the First Demographic Transition theory as proposed by Notestein. It is funny then how few articles actually try to establish this link. In fact we haven't been able to find any that used event-history analysis.[20] But given the theme akin to be an axiom, and also that in the large scale mortality decline did precede or coincide with the decline in fertility, then it could be the case that it has been taken for granted by most researchers.

What has perhaps been going unsaid here, and to state the basics, is the reason for the mortality relation: there exists some target family size, or a limit to the number of children a family needs, or can economically manage, depending on whether living in a rural or urban setting. The argument for a limiting family size, which causes the fertility reduction has been strongly advocated by Reher and Sanz-Gimeno (2010), but also in much of the older literature on stopping, starting with Henry (Henry 1961, p. 81).

Therefore in our view, and deriving from the mortality relation, when answering the adaption-or-innovation question, adaption seems to have been the case. That is, the population adapted to a new state of low mortality by decreasing its fertility accordingly.

Still, all of the previous has to be taken by a grain of salt – arguing for the adaption hypothesis in the context of the current work we have to remind ourselves of the following: first, we don't directly model the mortality-fertility relation in the regressions; second, the tables from which we draw the mortality information are somewhat biased as they don't control for age – an undoubtedly important factor for fertility. And third, we are not saying that innovation did not exist, but we do believe that it played a more local role, and to detect this would probably need a finer grained social group setting than what we used here.[21]

[20] The Reher and Sanz-Gimeno article (2010) uses some custom statistics to infer the relation. Many other papers measure the socioeconomic status as an affector of fertility.

[21] And a period perspective (rather than the cohort) would be more appropriate, as communication happens in calendar time.

We also saw a decrease in spacing, but what were the causes we can't really derive from the analysis. Going back to the idea of social capillarity that we discussed in the beginning, where in non-farming setting children become an economic burden rather than an asset, then one explanation could be derived from the same relation we used earlier – where decreased mortality caused decreased fertility. The hypothesis would go that, as parents had some idea of a good family size, and then at some point in historic time mortality decreased, it became possible for the mother to switch out from the indefinite state of childbearing (natural fertility) and to have the children in one streak instead. And with shorter birth intervals, this streak could be made even shorter still. On the other hand, the few articles we cited on long-term changes in spacing (Hionidou 1998; Reher and Sanz-Gimeno 2007) don't report a similar gradual decrease, and it is possible that we would see a different pattern if we controlled for more variables, as our current set is admittedly basic compared many other studies on the subject.

Finally, we'd also like to discuss the methodology that we used. We think the thesis showed that choosing a cohort perspective was well suited to separate the fertility decline by birth cohorts and parities, as the coefficients relate to actual experiences and is therefore easy to relate to and to interpret. Separating the models by parities helped us to look at their differently timed contributions to the fertility transition. The use of piece-wise constants was a good fit in bringing out the changes in timing of next birth. Put together, we have shown one way to look at the fertility transition as a whole with event-history methods. Given the availability of other variables, using them in these models appears to be a good approach in disentangling the various aspects of the fertility transition and determining causal mechanisms therein.

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A Appendix

A.1 Descriptives

Note: cohorts with bias are marked with a dagger (†), see section 6.1.

Table 3: Mean number of children born, children alive, and percentage of children dead among non-childless Estonian women by birth cohorts from 1845 to 1919

cohort	children born			children alive			difference (%)		
	urban	rural	both	urban	rural	both	urban	rural	both
1845-1852	5.7	4.9	5.0	3.8	3.4	3.4	32	30	31
1852-1859	4.9	5.2	5.1	3.1	3.6	3.6	36	29	30
1859-1866	4.5	5.0	4.9	3.0	3.5	3.4	32	28	29
1866-1873	4.7	4.9	4.8	3.2	3.5	3.4	30	27	28
1873-1880	4.0	4.7	4.5	3.0	3.5	3.3	25	25	25
1880-1887	3.5	4.3	4.1	2.7	3.3	3.1	22	23	23
1887-1894	3.1	3.7	3.5	2.6	3.0	2.9	16	18	17
1894-1901	2.8	3.5	3.3	2.4	3.0	2.8	13	14	14
1901-1908†	2.5	3.2	3.0	2.3	2.8	2.6	9	10	10
1908-1915†	2.5	2.9	2.8	2.3	2.6	2.5	7	9	9
1915-1919†	2.3	2.5	2.5	2.1	2.3	2.2	7	9	9

Table 4: Mean age by parity for Estonian women by birth cohorts from 1845 to 1919

cohort	parity						
	1	2	3	4	5	6	last
1845-1852	23.7	26.1	28.7	30.9	33.0	35.2	33.4
1852-1859	23.3	25.9	28.4	30.5	32.8	34.5	33.5
1859-1866	23.8	26.6	28.6	30.8	33.0	34.5	33.3
1866-1873	23.5	26.1	28.4	30.4	32.4	34.0	32.6
1873-1880	23.6	26.0	28.0	29.9	31.6	33.0	31.4
1880-1887	22.9	25.5	27.3	29.3	30.9	32.7	30.0
1887-1894	23.5	25.9	27.9	30.0	31.6	33.7	29.5
1894-1901	23.6	26.3	28.3	29.8	31.8	34.0	29.1
1901-1908†	23.4	25.9	27.9	29.6	31.8	32.9	28.0
1908-1915†	23.0	25.3	26.8	28.6	30.2	30.9	26.8
1915-1919†	21.2	23.1	24.6	26.5	27.3	30.3	23.6

Table 5: Number and proportion of Estonian women remained childless at death or censored, birth cohorts from 1845 to 1919

cohort	urban	rural	urban (%)	rural (%)
1845-1852	24	89	37	22
1852-1859	64	315	24	21
1859-1866	130	311	30	22
1866-1873	160	292	31	23
1873-1880	206	288	32	22
1880-1887	232	269	36	23
1887-1894	240	366	37	31
1894-1901	283	379	41	33
1901-1908†	302	431	43	37
1908-1915†	344	603	52	47
1915-1919†	245	635	61	63

Table 6: Number and proportion of births for Estonian women by urban-rural residency, birth cohorts from 1845 to 1919

cohort	urban	rural	urban (%)	rural (%)
1845-1852	192	1271	13	86
1852-1859	812	4868	14	85
1859-1866	1077	4535	19	80
1866-1873	1339	3903	25	74
1873-1880	1388	3769	26	73
1880-1887	1123	3128	26	73
1887-1894	943	2336	28	71
1894-1901	817	2067	28	71
1901-1908†	684	1750	28	71
1908-1915†	528	1432	26	73
1915-1919†	239	652	26	73

Table 7: Number and proportion of births for Estonian women by marital status, birth cohorts from 1845 to 1919

cohort	marital	non-marital	marital (%)	non-marital (%)
1845-1852	1371	92	93	6
1852-1859	5382	298	94	5
1859-1866	5312	300	94	5
1866-1873	4923	319	93	6
1873-1880	4791	366	92	7
1880-1887	3894	357	91	8
1887-1894	2971	308	90	9
1894-1901	2544	340	88	11
1901-1908†	2071	363	85	14
1908-1915†	1599	361	81	18
1915-1919†	682	209	76	23

A.2 Estimation results

Table 8: Interaction between urban-rural residency and cohort (E2)

	parity 2	parity 3	parities 4 and 5	parities 6 and 7
_t				
0-3 months	0.01***	0.01***	0.00***	0.01***
3-6 months	0.48***	0.29***	0.18***	0.21***
6-12 months	0.92*	0.57***	0.37***	0.38***
12-18 months	1.11**	1.00	0.73***	0.79***
18-24 months	1.00	1.00	1.00	1.00
24-30 months	0.92	0.98	0.89**	1.00
30-36 months	0.70***	0.66***	0.60***	0.72***
36-48 months	0.60***	0.54***	0.53***	0.48***
48-72 months	0.39***	0.40***	0.32***	0.27***
72-120 months	0.20***	0.19***	0.12***	0.08***
120-1000 months	0.03***	0.02***	0.01***	0.00***
rural × 1845-1852	1.13	1.18*	1.17*	1.28*
rural × 1852-1859	1.11*	1.31***	1.28***	1.34***
rural × 1859-1866	1.24***	1.33***	1.22***	1.25**
rural × 1866-1873	1.12*	1.26***	1.18**	1.23*
rural × 1873-1880	1.12*	1.18**	1.08	1.03
rural × 1880-1887	1.00	1.00	1.00	1.00
rural × 1887-1894	0.85**	0.86*	0.76***	0.78*
rural × 1894-1901	0.78***	0.80**	0.77***	
rural × 1901-1908	0.70***	0.65***	0.57***	
rural × 1908-1915	0.66***	0.56***		
rural × 1915-1919	0.49***	0.47***		
urban × 1845-1852	1.44*	1.62**	1.57**	1.30
urban × 1852-1859	1.22*	1.45***	1.16	1.20
urban × 1859-1866	1.24**	1.33***	1.12	1.07
urban × 1866-1873	1.24**	1.22*	1.20*	1.30*
urban × 1873-1880	1.24**	0.98	0.75***	0.83
urban × 1880-1887	0.93	0.76**	0.60***	0.56**
urban × 1887-1894	0.60***	0.58***	0.58***	0.73
urban × 1894-1901	0.53***	0.37***	0.52***	
urban × 1901-1908	0.40***	0.35***	0.43***	
urban × 1908-1915	0.38***	0.26***		
urban × 1915-1919	0.37***	0.18***		
15-20	1.10*	1.52**	1.35	
20-25	1.00	1.00	1.00	1.00
25-30	0.81***	0.77***	0.75***	0.85
30-35	0.60***	0.51***	0.52***	0.57
35-40	0.40***	0.34***	0.28***	0.33**
40-45	0.11***	0.09***	0.09***	0.09***
45-50	0.00	0.00	0.00	0.01***
Observations	70067	61930	73971	31971

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 9: Interaction between cohort and duration since last birth (E3)

	parity 2	parity 3	parity 4-5	parity 6-7
_t				
1845-1864 × 0-3 months	0.01***	0.00***	0.00***	0.00***
1845-1864 × 3-6 months	0.26***	0.18***	0.14***	0.17***
1845-1864 × 6-12 months	0.61***	0.35***	0.26***	0.31***
1845-1864 × 12-18 months	0.95	0.80**	0.66***	0.73**
1845-1864 × 18-24 months	1.00	1.00	1.00	1.00
1845-1864 × 24-30 months	0.96	1.04	1.04	1.10
1845-1864 × 30-36 months	0.85	0.71***	0.68***	0.70**
1845-1864 × 36-48 months	0.61***	0.58***	0.61***	0.48***
1845-1864 × 48-72 months	0.49***	0.47***	0.38***	
1845-1864 × 72-120 months	0.19***	0.20***		
1845-1864 × 120-1000 months	0.02***	0.01***		
1864-1883 × 0-3 months	0.01***	0.00***	0.00***	0.00***
1864-1883 × 3-6 months	0.41***	0.24***	0.16***	0.20***
1864-1883 × 6-12 months	0.83**	0.48***	0.35***	0.37***
1864-1883 × 12-18 months	1.04	0.85*	0.69***	0.71***
1864-1883 × 18-24 months	0.99	0.84*	0.92	0.89
1864-1883 × 24-30 months	0.76**	0.82*	0.71***	0.78*
1864-1883 × 30-36 months	0.63***	0.53***	0.51***	0.67***
1864-1883 × 36-48 months	0.57***	0.42***	0.42***	0.36***
1864-1883 × 48-72 months	0.32***	0.31***	0.27***	
1864-1883 × 72-120 months	0.17***	0.15***		
1864-1883 × 120-1000 months	0.02***	0.01***		
1883-1902 × 0-3 months	0.01***	0.00***	0.00***	0.01***
1883-1902 × 3-6 months	0.34***	0.17***	0.15***	0.22***
1883-1902 × 6-12 months	0.66***	0.39***	0.32***	0.31***
1883-1902 × 12-18 months	0.68***	0.61***	0.50***	0.62***
1883-1902 × 18-24 months	0.49***	0.51***	0.59***	0.56***
1883-1902 × 24-30 months	0.52***	0.41***	0.49***	0.57***
1883-1902 × 30-36 months	0.32***	0.30***	0.29***	0.41***
1883-1902 × 36-48 months	0.33***	0.26***	0.30***	0.36***
1883-1902 × 48-72 months	0.21***	0.18***	0.17***	
1883-1902 × 72-120 months	0.11***	0.09***		
1883-1902 × 120-1000 months	0.02***	0.01***		
1902-1919 × 0-3 months	0.00***	0.01***	0.00	0.00
1902-1919 × 3-6 months	0.33***	0.21***	0.18***	0.33**
1902-1919 × 6-12 months	0.47***	0.32***	0.38***	0.33***
1902-1919 × 12-18 months	0.43***	0.35***	0.31***	0.32***
1902-1919 × 18-24 months	0.34***	0.20***	0.39***	0.55*
1902-1919 × 24-30 months	0.33***	0.27***	0.28***	0.38**
1902-1919 × 30-36 months	0.26***	0.19***	0.20***	0.49*
1902-1919 × 36-48 months	0.20***	0.16***	0.22***	0.27***
1902-1919 × 48-72 months	0.14***	0.12***	0.11***	
1902-1919 × 72-120 months	0.09***	0.06***		
1902-1919 × 120-1000 months	0.03***	0.03***		
15-20	1.10*	1.52**	0.85	
20-25	1.00	1.00	1.00	1.00
25-30	0.81***	0.76***	0.77***	0.73
30-35	0.60***	0.51***	0.54***	0.52*
35-40	0.41***	0.34***	0.30***	0.31***

40-45	0.11***	0.09***	0.11***	0.09***
45-50	0.00	0.00	0.00	0.01***
Observations	70067	61930	70687	29635

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 10: Interaction between urban-rural residency, cohort and duration since last birth (E4)

	parity 2	parity 3	parity 4-5	parity 6-7
_t				
1845-1864 × rural × 0-3 months	0.01***	0.00***	0.00***	0.00***
1845-1864 × rural × 3-6 months	0.26***	0.14***	0.13***	0.15***
1845-1864 × rural × 6-12 months	0.62***	0.33***	0.25***	0.29***
1845-1864 × rural × 12-18 months	0.94	0.78**	0.64***	0.69***
1845-1864 × rural × 18-24 months	1.00	1.00	1.00	1.00
1845-1864 × rural × 24-30 months	1.00	1.08	1.05	1.11
1845-1864 × rural × 30-36 months	0.88	0.76**	0.75***	0.71**
1845-1864 × rural × 36-48 months	0.62***	0.55***	0.65***	0.44***
1845-1864 × rural × 48-72 months	0.53***	0.50***	0.40***	
1845-1864 × rural × 72-120 months	0.22***	0.20***		
1845-1864 × rural × 120-1000 months	0.02***	0.01***		
1845-1864 × urban × 0-3 months	0.01***	0.00	0.01***	0.01***
1845-1864 × urban × 3-6 months	0.34***	0.37***	0.18***	0.20***
1845-1864 × urban × 6-12 months	0.73*	0.47***	0.31***	0.30***
1845-1864 × urban × 12-18 months	1.35*	0.96	0.77*	0.73
1845-1864 × urban × 18-24 months	1.30	1.08	1.02	0.64*
1845-1864 × urban × 24-30 months	1.00	0.87	0.97	0.68
1845-1864 × urban × 30-36 months	0.96	0.52*	0.35***	0.44**
1845-1864 × urban × 36-48 months	0.68	0.81	0.43***	0.51**
1845-1864 × urban × 48-72 months	0.35***	0.36***	0.31***	
1845-1864 × urban × 72-120 months	0.10***	0.20***		
1845-1864 × urban × 120-1000 months	0.03***	0.02***		
1864-1883 × rural × 0-3 months	0.01***	0.00***	0.00***	0.01***
1864-1883 × rural × 3-6 months	0.35***	0.22***	0.16***	0.16***
1864-1883 × rural × 6-12 months	0.77**	0.43***	0.31***	0.34***
1864-1883 × rural × 12-18 months	1.07	0.86	0.72***	0.66***
1864-1883 × rural × 18-24 months	1.01	0.89	0.93	0.88
1864-1883 × rural × 24-30 months	0.81*	0.91	0.83*	0.82
1864-1883 × rural × 30-36 months	0.70***	0.57***	0.56***	0.69**
1864-1883 × rural × 36-48 months	0.63***	0.45***	0.44***	0.35***
1864-1883 × rural × 48-72 months	0.34***	0.33***	0.31***	
1864-1883 × rural × 72-120 months	0.20***	0.17***		
1864-1883 × rural × 120-1000 months	0.02***	0.01***		
1864-1883 × urban × 0-3 months	0.00***	0.00***	0.00***	0.00
1864-1883 × urban × 3-6 months	0.66***	0.28***	0.18***	0.29***
1864-1883 × urban × 6-12 months	1.10	0.62***	0.46***	0.39***
1864-1883 × urban × 12-18 months	1.15	0.87	0.63***	0.70*
1864-1883 × urban × 18-24 months	1.11	0.75*	0.90	0.73*
1864-1883 × urban × 24-30 months	0.75*	0.62***	0.42***	0.50***
1864-1883 × urban × 30-36 months	0.52***	0.46***	0.40***	0.49***
1864-1883 × urban × 36-48 months	0.48***	0.38***	0.38***	0.30***
1864-1883 × urban × 48-72 months	0.31***	0.26***	0.18***	
1864-1883 × urban × 72-120 months	0.15***	0.10***		
1864-1883 × urban × 120-1000 months	0.02***	0.00***		
1883-1902 × rural × 0-3 months	0.01***	0.01***	0.00	0.01***
1883-1902 × rural × 3-6 months	0.38***	0.17***	0.17***	0.20***
1883-1902 × rural × 6-12 months	0.76***	0.42***	0.34***	0.26***

1883-1902 × rural × 12-18 months	0.75**	0.70***	0.55***	0.58***
1883-1902 × rural × 18-24 months	0.56***	0.61***	0.62***	0.54***
1883-1902 × rural × 24-30 months	0.61***	0.48***	0.52***	0.57***
1883-1902 × rural × 30-36 months	0.34***	0.37***	0.35***	0.45***
1883-1902 × rural × 36-48 months	0.43***	0.32***	0.32***	0.35***
1883-1902 × rural × 48-72 months	0.26***	0.21***	0.20***	
1883-1902 × rural × 72-120 months	0.13***	0.11***		
1883-1902 × rural × 120-1000 months	0.02***	0.01***		
1883-1902 × urban × 0-3 months	0.00***	0.00	0.01***	0.00
1883-1902 × urban × 3-6 months	0.32***	0.18***	0.10***	0.20**
1883-1902 × urban × 6-12 months	0.57***	0.31***	0.27***	0.45**
1883-1902 × urban × 12-18 months	0.62***	0.43***	0.34***	0.64
1883-1902 × urban × 18-24 months	0.43***	0.32***	0.52***	0.48*
1883-1902 × urban × 24-30 months	0.43***	0.30***	0.38***	0.37*
1883-1902 × urban × 30-36 months	0.31***	0.20***	0.15***	0.10**
1883-1902 × urban × 36-48 months	0.21***	0.16***	0.26***	0.32**
1883-1902 × urban × 48-72 months	0.17***	0.13***	0.09***	
1883-1902 × urban × 72-120 months	0.08***	0.06***		
1883-1902 × urban × 120-1000 months	0.01***	0.01***		
1902-1919 × rural × 0-3 months	0.01***	0.01***	0.00	0.00
1902-1919 × rural × 3-6 months	0.39***	0.21***	0.17***	0.31**
1902-1919 × rural × 6-12 months	0.56***	0.35***	0.37***	0.30***
1902-1919 × rural × 12-18 months	0.58***	0.42***	0.31***	0.31***
1902-1919 × rural × 18-24 months	0.42***	0.24***	0.39***	0.51*
1902-1919 × rural × 24-30 months	0.41***	0.31***	0.31***	0.48*
1902-1919 × rural × 30-36 months	0.31***	0.26***	0.19***	0.49
1902-1919 × rural × 36-48 months	0.24***	0.21***	0.21***	0.27***
1902-1919 × rural × 48-72 months	0.18***	0.14***	0.11***	
1902-1919 × rural × 72-120 months	0.11***	0.07***		
1902-1919 × rural × 120-1000 months	0.03***	0.03***		
1902-1919 × urban × 0-3 months	0.00	0.01***	0.00	0.00
1902-1919 × urban × 3-6 months	0.26***	0.20***	0.21***	0.30
1902-1919 × urban × 6-12 months	0.35***	0.21***	0.41**	0.42
1902-1919 × urban × 12-18 months	0.22***	0.19***	0.31**	0.23
1902-1919 × urban × 18-24 months	0.24***	0.10***	0.40**	0.57
1902-1919 × urban × 24-30 months	0.24***	0.17***	0.15**	0.00
1902-1919 × urban × 30-36 months	0.22***	0.02***	0.29**	0.30
1902-1919 × urban × 36-48 months	0.16***	0.06***	0.26***	0.18
1902-1919 × urban × 48-72 months	0.10***	0.09***	0.10***	
1902-1919 × urban × 72-120 months	0.08***	0.04***		
1902-1919 × urban × 120-1000 months	0.03***	0.02***		
15-20	1.09	1.50**	0.95	
20-25	1.00	1.00	1.00	1.00
25-30	0.82***	0.76***	0.76***	0.75
30-35	0.60***	0.51***	0.53***	0.53
35-40	0.40***	0.34***	0.30***	0.31***
40-45	0.11***	0.09***	0.10***	0.09***
45-50	0.00	0.00	0.00	0.01***
Observations	70067	61930	70687	29635

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure 17: Hazard ratios at piece-wise constant durations after birth on transition to parity 2 by urban-rural residency for cohort 1845-1864. Risk relative to rural population at 18-24 months after birth (E4).

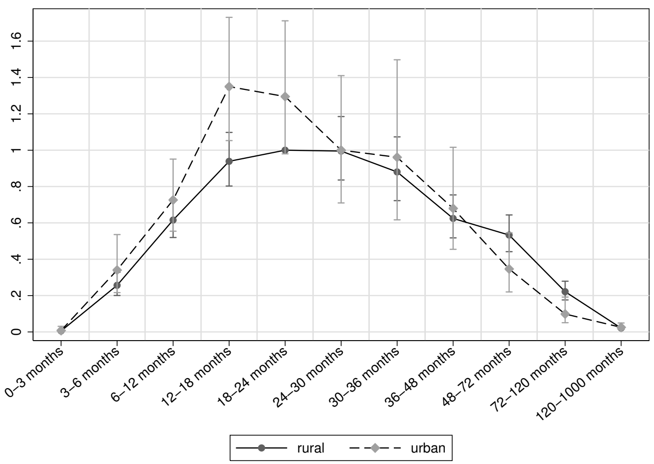

Figure 18: Hazard ratios at piece-wise constant durations after birth on transition to parity 2 by urban-rural residency for cohort 1864-1883. Risk relative to rural population at 18-24 months after birth (E4).

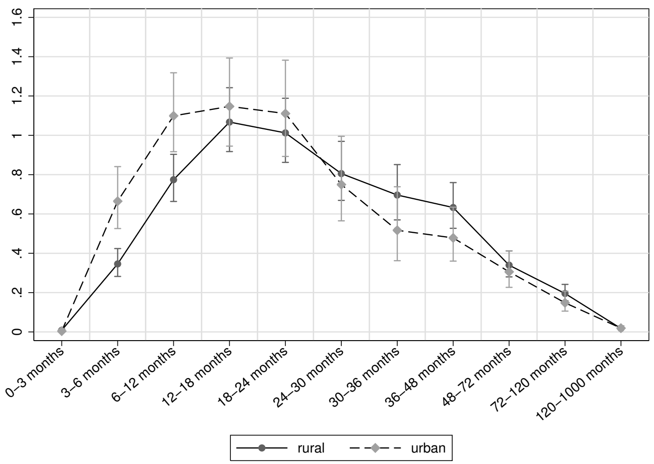

Figure 19: Hazard ratios at piece-wise constant durations after birth on transition to parity 2 by urban-rural residency for cohort 1883-1902. Risk relative to rural population at 18-24 months after birth (E4).

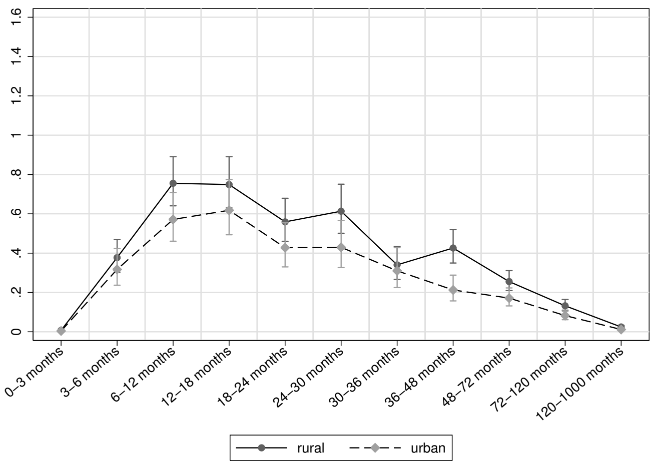

Figure 20: Hazard ratios at piece-wise constant durations after birth on transition to parity 2 by urban-rural residency for cohort 1902-1921. Risk relative to rural population at 18-24 months after birth (E4).

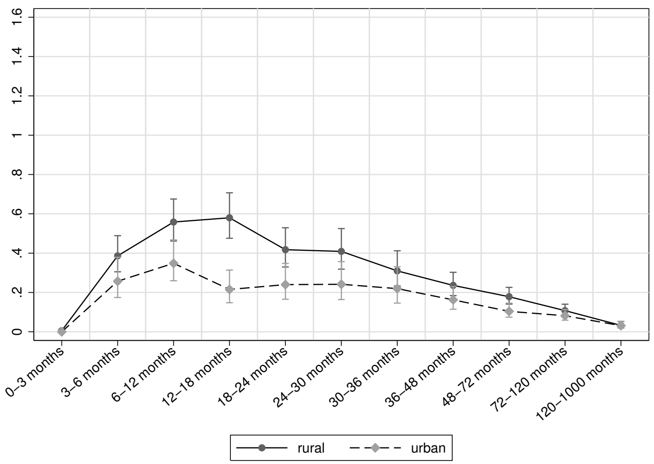

Figure 21: Hazard ratios at piece-wise constant durations after birth on transition to parity 3 by urban-rural residency for cohort 1845-1864. Risk relative to rural population at 18-24 months after birth (E4).

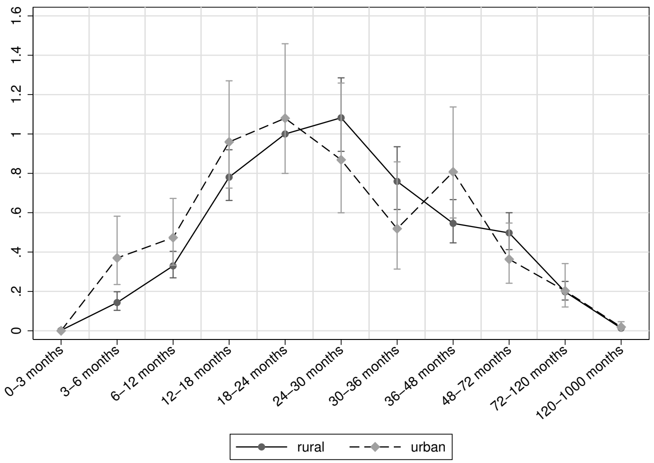

Figure 22: Hazard ratios at piece-wise constant durations after birth on transition to parity 3 by urban-rural residency for cohort 1864-1883. Risk relative to rural population at 18-24 months after birth (E4).

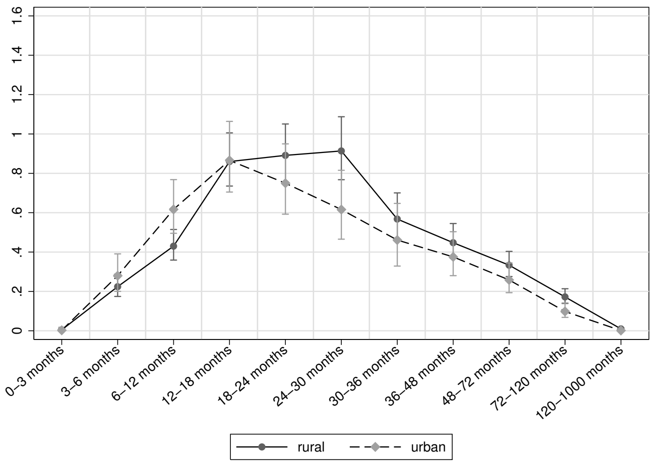

Figure 23: Hazard ratios at piece-wise constant durations after birth on transition to parity 3 by urban-rural residency for cohort 1883-1902. Risk relative to rural population at 18-24 months after birth (E4).

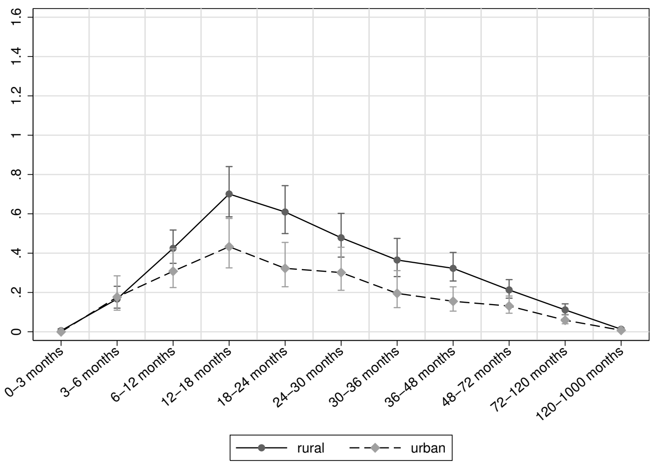

Figure 24: Hazard ratios at piece-wise constant durations after birth on transition to parity 3 by urban-rural residency for cohort 1902-1921. Risk relative to rural population at 18-24 months after birth (E4).

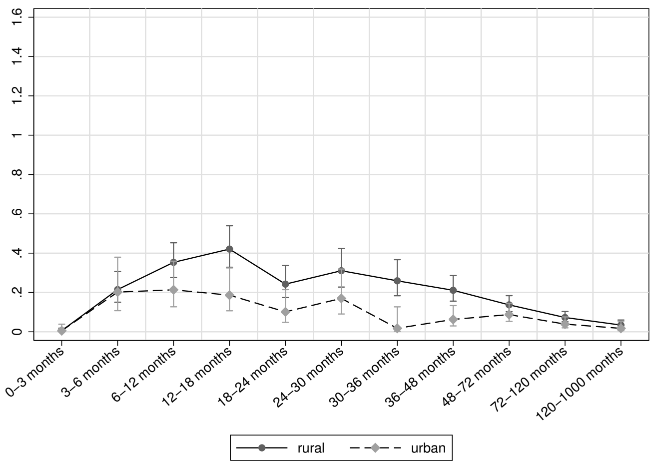

Figure 25: Hazard ratios at piece-wise constant durations after birth on transition to parities 4-5 by urban-rural residency for cohort 1845-1864. Risk relative to rural population at 18-24 months after birth (E4).

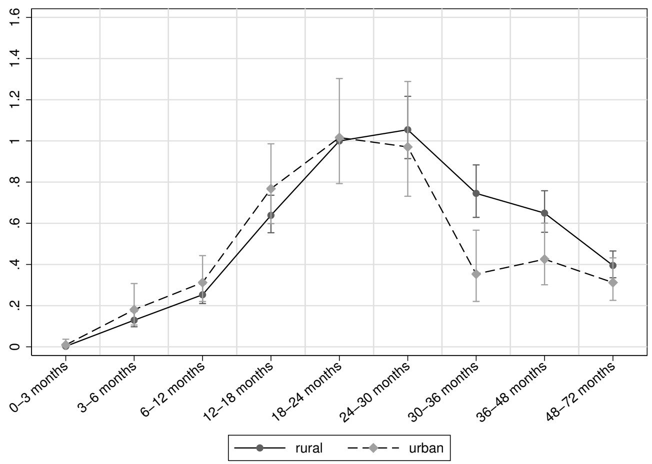

Figure 26: Hazard ratios at piece-wise constant durations after birth on transition to parities 4-5 by urban-rural residency for cohort 1864-1883. Risk relative to rural population at 18-24 months after birth (E4).

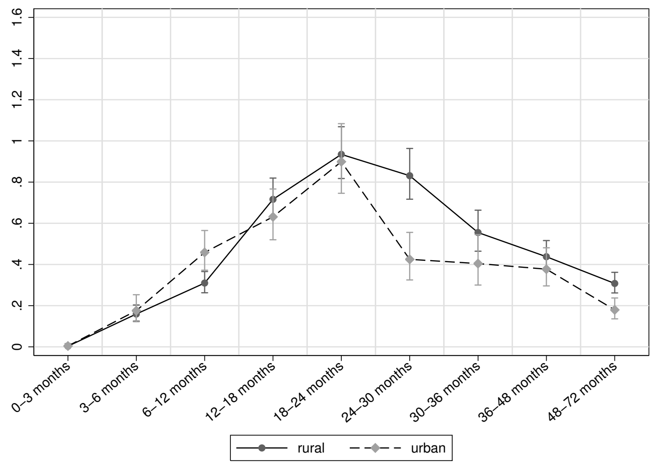

Figure 27: Hazard ratios at piece-wise constant durations after birth on transition to parities 4-5 by urban-rural residency for cohort 1883-1902. Risk relative to rural population at 18-24 months after birth (E4).

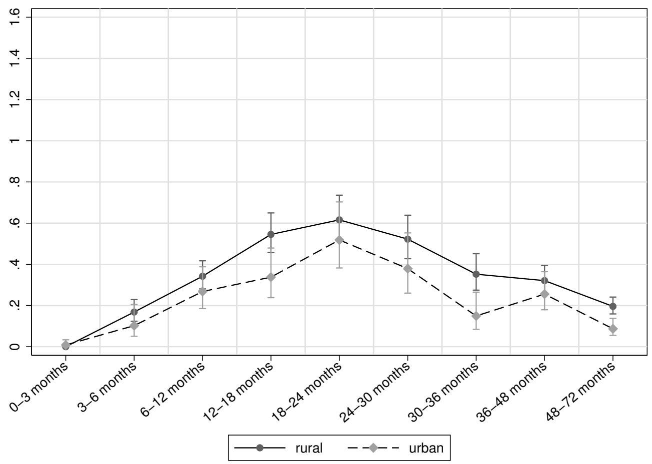

Figure 28: Hazard ratios at piece-wise constant durations after birth on transition to parities 4-5 by urban-rural residency for cohort 1902-1921. Risk relative to rural population at 18-24 months after birth (E4).

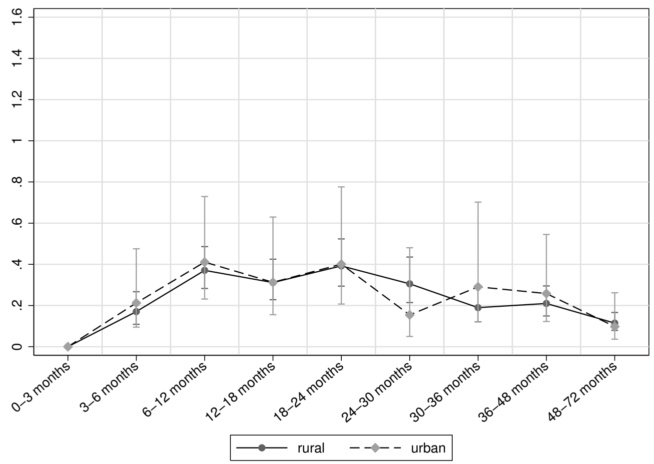

Figure 29: Hazard ratios at piece-wise constant durations after birth on transition to parities 6-7 by urban-rural residency for cohort 1845-1864. Risk relative to rural population at 18-24 months after birth (E4).

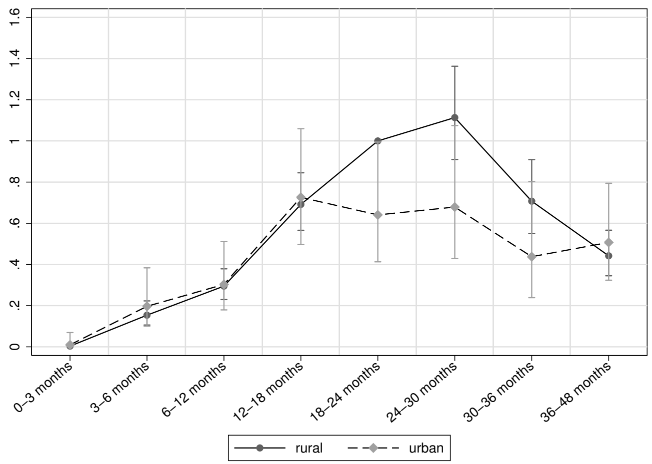

Figure 30: Hazard ratios at piece-wise constant durations after birth on transition to parities 6-7 by urban-rural residency for cohort 1864-1883. Risk relative to rural population at 18-24 months after birth (E4).

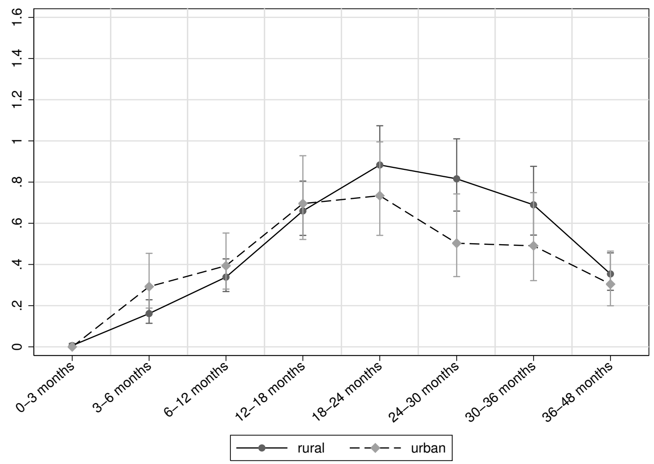

Figure 31: Hazard ratios at piece-wise constant durations after birth on transition to parities 6-7 by urban-rural residency for cohort 1883-1902. Risk relative to rural population at 18-24 months after birth (E4).

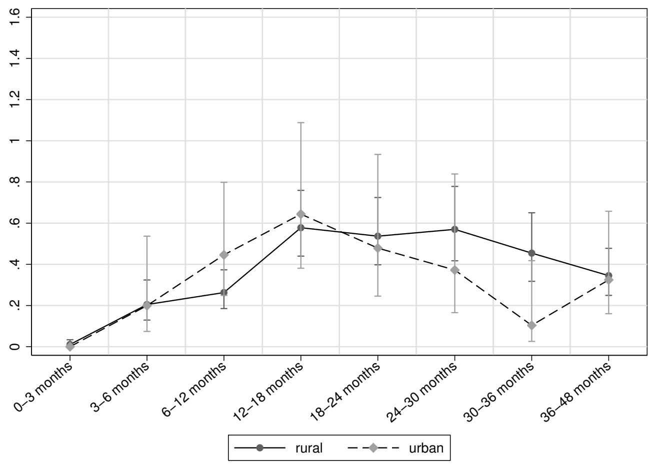

Figure 32: Hazard ratios at piece-wise constant durations after birth on transition to parities 6-7 by urban-rural residency for cohort 1902-1921. Risk relative to rural population at 18-24 months after birth (E4).