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Determinants of Fertility During the Fertility Transition in Estonia: A Spatial Analysis

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Abstract
The Princeton European Fertility Project famously studied the determinants of fertility transition using geographical data. The project, however, received criticism for using high-level spatial units that hide much of the variation within. Additionally, although the project underlined the importance of neighbourhood influence through linguistic and cultural similarities, the spatial aspects were not comprehensively studied. This article investigates fertility determinants during the second half of the fertility transition in Estonia, a country with one of the earliest transitions in Europe. We study the completed cohort fertility of married women born between 1875 and 1894 in Estonia at the lowest-level of municipalities. Given the spatial nature of the data, spatial Durbin models are used in addition to the OLS model. The results show that demographic, cultural, educational, economic and spatial influences were all important in determining the level of fertility during the transition.

Keywords Fertility · Demographic transition · Estonia · Spatial analysis · Historical demography

1 Introduction

Estonia was one of the earliest societies in Europe (and hence the world) that experienced the fertility transition. From the 1860 to 1930s, the number of children born per woman decreased from traditional high levels (4.5 children per woman) to modern low levels (2 children per woman) (Gortfelder & Puur, 2019). Such a demographic transformation could only be completed with a drastic change in fertility

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behaviour. Similar to many other countries in Europe at the time of the fertility transition, the material motivation for and the ideational-moral acceptance of the adoption of new behaviour, however, was not formed at the same time and with the same intensity in all parts of the country. Considerable regional variation in fertility developed during the modernisation process.

Geography has played an important role in the wider debate of historical fertility decline and its causes. Numerous papers have explored the role of geography in understanding spatial patterns of fertility and their spread across communities. One of the main focuses of these studies has been to analyse regional differences in fertility in the second half of the 19th and early twentieth century by highlighting regions of early adopters of new demographic behaviour, and to explore if the spread of fertility decline could be explained by compositional and structural factors, or by social diffusion mechanisms (Coale & Watkins, 1986; Goldstein & Klüsener, 2014).

The aim of this paper is to investigate the spatial variation in fertility in Estonia and factors related to this. Our paper contributes to the literature on spatial variations in fertility by examining regional patterns of fertility in a never-before-studied context in great spatial detail. We explore the role of economic, socio-cultural and spatial factors in one of the earliest fertility transitions in Europe.

This paper is structured as follows. The next section provides an overview of previous literature on historical fertility transition and its spatial aspects. The third section presents a brief introduction to the Estonian context. The following section introduces our main data sources, variables of interest, and our statistical approach. The fifth section describes the results of the analyses, and the final section focusses on a general discussion of our findings.

2 Fertility Transition in Europe and its Spatial Aspects

Ansley Coale (1973) famously proposed the Ready-Willing-Able (RWA) model to make sense of the causes related to the adoption of novel fertility behaviour during the fertility transition. These factors have also been described as structural, cultural and technological (van de Kaa, 1994). According to the model, all three dimensions are needed to initiate a change in behaviour. In other words, there must be a material motivation for adopting new behaviour, the prevailing cultural-moral norms should not contradict it, and individuals must have a knowledge of the methods that can enable them to act on their motivation.

Starting from the technological dimension, the European fertility declines had largely been completed before the mass production of contraception, which implies primary reliance on more "traditional" methods, at least during the first half of the fertility decline (Szreter & Fisher, 2010). Withdrawal was probably of central importance to the stopping behaviour that emerged with the transition. The practice was known long before demographic modernisation, and was used for increasing birth intervals and avoiding pre-marital pregnancies (Santow, 1995). The use of the calendar method was probably also widespread. Thus, the adoption of novel family planning behaviour was not hampered by the question of how this ought to be done.

In terms of readiness or structure, the fertility transition has been originally associated with the emergence and spread of industrialisation and urbanisation, which changed the material motivations for childbearing (Davis, 1945; Notestein, 1945). These accounts based their supposition on contemporary observations that in the industrialising societies, the social classes and geographic areas most affected by economic modernisation were the pioneers in adopting the new fertility behaviour (for an overview of the literature at the time see Mombert, 1907, pp. 129–170).

On the other hand, the results of the Princeton Project (Coale & Watkins, 1986) and the influential monograph by Simon Szreter (1996) on the British case, cast doubt on this hypothesis by underlining the importance of cultural and spatial aspects of the fertility transition. This revisionist view, however, has not become the new consensus. The methodology of the Princeton Project has been convincingly criticised (Brown & Guinnane, 2002, 2007; Guinnane et al., 1994), and the data and research used by Szreter have been subjected to reanalysis and an opposing interpretation, which further emphasized the role of the socio-economic dimension in the historical fertility transition (Barnes & Guinnane, 2012; Jaadla et al., 2020).

In addition to macro-level structural and cultural factors, it is important to point out that the decrease of infant and child mortality, which partly preceded and partly ran in parallel of the fertility transition, also crucially changed the material motivation of having children. Since parents had to take into account that more children survived past age 5, and even to adulthood, which increased child-raising costs. The Princeton European Fertility Project failed to support the established theoretical understanding that an increase in child survival was a precondition of the decline in fertility (Van de Walle, 1986, p. 233). However, several recent studies have shown the importance of the link between infant and child mortality and fertility during the demographic transition (Gortfelder & Puur, 2020; Reher & Sandström, 2015; Reher & Sanz-Gimeno, 2007; Reher et al., 2017; Van Poppel et al., 2012). Also, a more refined use of macro-level data supports this view (Sánchez-Barricarte, 2017).

Another important aspect in understanding historical fertility transition may be secularisation, which was gaining a foothold in Europe during the 19th and early twentieth centuries. Secularisation may affect fertility in different ways. First, secularisation is associated with the decrease of fatalism and a more active sense of agency. Thus, traditional societies have not seen childbearing as being within an individual's calculus of choice, whereas more modern and secular societies placed a strong emphasis on individual responsibility and planning (Coale, 1973). Second, traditional fertility behaviour is insured by the control of the collective, which further constrained individual choice (Ryder, 2010). The clergyman and the religious congregation can be seen as crucial bastions of this traditional collective control. Previous studies have found evidence between votes given to secular political parties (as a proxy for secularisation) and fertility transition in Belgium and Prussia (Galloway, 2009; Lesthaeghe, 1977). Another recent paper demonstrates how the early secularisation in France is the primary reason for its early onset of fertility transition (Blanc, 2021).

The explanation frameworks of fertility decline in the literature also often broadly distinguish a dichotomy of mechanism which attribute declining fertility to the changing transformation of social and economic environment ('adaptation'), and to the diffusion of new norms and attitudes related to fertility behaviour ('innovation') (Carlsson, 1966). The timing and speed of these structural and behavioural changes across Europe, but also within countries, has been an important consideration in putting together the factors behind the spatiotemporal patterns of fertility decline.

The main mechanisms of spatial fertility variation are complex and often difficult to disentangle. In part, the observed fertility differences are a consequence of contextual factors related to local economic conditions and socio-cultural family norms. At the same time, the individuals and their characteristics (social status, religious-cultural background, educational attainment) also influence the composition of local populations, which has influenced the fertility variations observed at a macro-level, or in return have had an impact on the contextual factors of a local area (Basten et al., 2012). In this way, a large body of literature has shown the importance of socio-economic factors during the fertility transition. First of all, fertility behaviour of individuals in historical context was clearly influenced by their socio-economic status with a consistent, although not linear pattern of earlier fertility limitation among higher social classes across historical settings (Dribe et al., 2014, 2017; Gortfelder et al., 2020; Jaadla et al., 2020; Klüsener et al., 2019). Similarly, at the macro-level, higher levels of economic development have also been consistently associated with lower levels of fertility (Becker, 1960; Cleland & Wilson, 1987; Dribe, 2009; Goldstein & Klüsener, 2014; Guinnane, 2011; Haines & Hacker, 2011).

Sociocultural dimension is highly relevant in shaping spatial fertility variation. Social diffusion mechanisms have been essential for understanding the spread of new forms of fertility behaviour during the first and the second demographic transition (Lesthaeghe & Neels, 2002). The influential work by the Princeton Project emphasized the importance of regional cultural setting and cultural-linguistic similarities in explaining variations in fertility across historical Europe (Coale & Watkins, 1986). Subsequent studies which have often taken a spatial perspective have supported these findings in the context of historical fertility transition in Prussia (Goldstein & Klüsener, 2014), Sweden (Junkka, 2019), and Belgium (Costa et al., 2021a), France (Daudin et al., 2019; González-Bailón & Murphy, 2013; Murphy, 2015), and Paris (Brée & Doignon, 2022). Furthermore, spatial analysis framework has been important in highlighting the relationship between fertility change and geographical dimension and spatial diffusion process in more recent fertility patterns in Brazil (Potter et al., 2010; Schmertmann et al., 2008), Italy (Salvati et al., 2020; Vitali & Billari, 2017), Spain (Burillo et al., 2020; Sabater & Graham, 2019), Egypt (Doignon et al., 2021), and Europe (Campisi et al., 2020).

3 The Estonian Context

In the 19th and early twentieth centuries, the area of modern-day Estonia was divided between the governorates of Estland and Livland, which, together with Kurland, comprised the Baltic provinces of the Russian Empire. The central authorities in St. Petersburg allowed them considerable autonomy in their internal affairs. The political, economic and cultural life of the provinces was significantly influenced by the Baltic German minority, which, although a small fraction of the

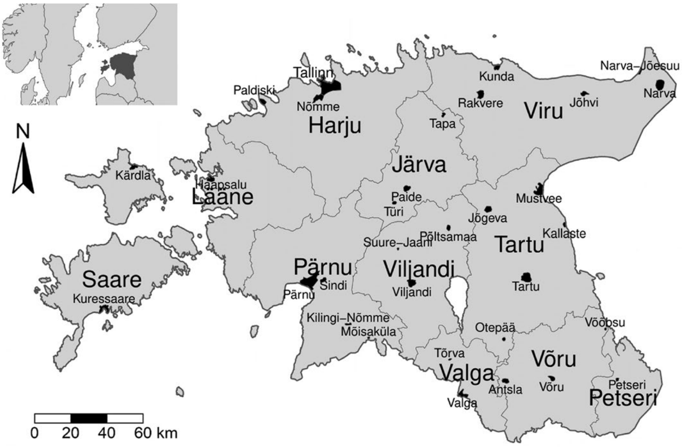

Fig. 1 The counties and towns of Estonia in the 1920s. *Base map:* Roosaare, J., Liiber, Ü. Aunap, R., Järvet., Pragi, U., Tihemets, K. 2000. *Eesti geograafia CD*. [Estonian Geography]Tartu: Tartu University

total population, constituted the vast majority of the local elite until the establishment of the Republic of Estonia in 1918 (Kasekamp, 2010; Raun, 2002).

Estonia experienced industrialisation at the end of the 19th and beginning of the twentieth centuries. The primary industrial enterprises were developed in Tallinn, Narva and some smaller towns. However, this was at a lower scale than in Western Europe with many medieval towns retained their old commercial-artisanal outlook. Consequently, Estonian society remained primarily agrarian (Kahk & Tarvel, 1997). At the time of the 1897 census, less than one fifth of the population lived in urban areas; by 1934, this figure had increased to 31 per cent (Riigi Statistika Keskbüroo, 1924a, 1935). In terms of GDP *per capita,* Estonia was behind most countries for which this data is available from the time (Norkus & Markevičiūtė, 2021). Still, there were many changes in the countryside, including multiple agrarian innovations and the development of a more market-oriented approach. These developments were not evenly spread across the country, however. The pioneering areas (consult Fig. 1) tended to be in Viljandi, Järva, and some parts of Pärnu and Tartu counties (Raun, 2002, pp. 68–70; Laur, et al., 2014).

Estonia was also at the forefront of mass literacy: by 1881, over 90 per cent of adults were able to read (Raun, 1979). By 1922 almost 90 per cent of the population could both read and write. This phenomenon is related to the dominance of Lutheranism, which also corresponds with the bigger picture that fertility modernisation tended to begin earlier in the Protestant areas of Europe (Coale & Watkins 1986), and is thought to be associated with the effect that Protestant teachings had on literacy and the establishment of a primary education system (Aarma, 1990; Andresen, 2003) that enabled it for both sexes (Becker & Woessmann, 2008). Here as well, some regional differences were present with again Southern and Central Estonia achieving better educational results, as did of course the urban centres.

Literacy was the basis of ideational modernisation. Schools needed teachers, which resulted in the introduction of lower-level intellectuals throughout the rural areas. The role of village school teachers in expanding not only their pupils' but also their communities' horizons has been emphasised in Estonian historiography (Karjahärm & Sirk, 1997, pp. 109–147). Literacy enabled the diffusion of literature that urged people to better their lives by means of hard work and the adoption of modern economic techniques. This line of literature was introduced by the Baltic Germans influenced by the German Enlightenment, who began to publish in the local vernaculars (Noodla, 1986). Improvements in education and the upsurge in reading gave birth to a new mentality among the wider population, which inculcated what could be called a "modern work ethic". Attaining higher levels of culture and material prosperity at both a personal and national level was an important goal for many Estonians. This aspirational mentality would conflict with sustained high fertility.

It was also relevant that the usual defender of traditional morals, the Church, held a somewhat weaker sway over the lives of the people of the Baltic provinces. There were two reasons for this. First, the vast majority of the Lutheran clergy before 1918 were Baltic Germans, which weakened the strength of their bond to their Estonian congregations, a recurring topic in the local Church history (Saard, 2020). Second, the Lutheran Church was not the state church, and was therefore less able to impose compliance with its family norms. This means that two of the three elements[1] that have been emphasised as crucial in ensuring the influence of religion on fertility were missing in the Baltic provinces (McQuillian, 2004).

Evidence with regard to mortality and fertility during the demographic modernisation in Estonia is mainly available from aggregate data, which for the nineteenth century is not always trustworthy due to unregistered emigration. Notwithstanding short-term fluctuations, a slow decline in the crude death and birth rates can be observed during the first half of the nineteenth century; the decline began to accelerate after the 1860s (Katus, 1989). The earliest life table estimates for the three Baltic provinces show a life expectancy of 39.1 years for males and 42.7 years for females in 1880–83 (Besser & Ballod, 1897). These estimates are superior to those for the rest of the Russian Empire, and also exceed the estimates for Bavaria and Prussia, but lag behind those of France, England and Wales, and the Scandinavian countries (Vallin et al., 2017). Overall, the mortality transition was slow. Thus, by 1938, the male and female life expectancies were at 55.5 and 61.9 years (Katus & Puur, 2004), respectively, still quite far off from those in countries that had reached the end of the demographic transition by the 1930s. Thus, Estonia experienced largely parallel mortality and fertility decreases, with a comparatively small population increase (so-called French type of demographic transition).

The findings obtained within the framework of the Princeton European Fertility Project show that Estonia was among the pioneers of the fertility transition. In the early 1880s, only France and Hungary had lower marital fertility than Estonia (Katus, 1994). The date by which marital fertility had fallen by 10 per cent was

[1] The third being that the organised religion must also explicitly state the expected behavioural norms with respect to fertility.

estimated to be 1888 for Estonia; this resembles estimates for Western Europe, and closely matches those for Germany (Coale & Watkins, 1986). In cohort terms, it is evident that fertility started to decline among the cohorts of women born in the 1830s. The mean number of children for women born at the very end of the nineteenth century was already at two per woman (Gortfelder & Puur, 2019).

Regarding nuptiality, the Baltic provinces were characterised by the typical (Western) European marriage pattern (Hajnal, 1965). In the Estland governorate, the female mean age of marriage in 1897 was 26.3 years, and the proportion of never-married was 12 per cent (age 40–49). However, also with regards to these indicators, there were many instances of spatial variation (Gortfelder, 2021a).

4 Data and Methods

4.1 Dependent Variable

Most macro-level fertility analyses of spatial data use some period fertility indicator derived from aggregated data (such as published census results). In the case of Estonia, the nineteenth century published census reports provide information only at high level of aggregation, usually only distinguishing counties and towns.[2] The first census of the twentieth century did not take place until 1922. The 1922 census publications provide information also at the municipality-level, and with enough detail to compute child-woman ratios.[3] However, in this analysis we use them in a supporting function for four reasons. First, the census results are rather late when it comes to the fertility transition in Estonia. Second, the child-woman ratio is also a relatively crude measure and importantly, it is an estimate of the level of general fertility.[4] Thus, spatial variation in the share that remain single highly influence it. Previous research has shown considerable variation in the share of never-married for Estonia at the end of the 19th and early twentieth centuries (Gortfelder, 2021a). In the context of the fertility transition, however, we are interested in changes in marital fertility behaviour, whereas decreasing general fertility by increasing the proportion remaining single is not our interest, since this is not novel behaviour. Third, the child-woman ratio does not provide knowledge on the level of infant and child mortality, which is also an important aspect in explaining (the spatial variation of) fertility during the demographic transition, since individuals and areas with higher mortality tended to have higher fertility (Gortfelder & Puur, 2020; Reher et al., 2017; Sánchez-Barricarte, 2017). Finally, differences in the more precise age-structure of

[2] The micro-level data was mostly destroyed after the results were compiled.

[3] Child-woman ratio is a ratio between the number of children under age 5 and the number of women aged 15–49.

[4] We are unable to compute a child-woman ratio for married women from the published census results, since marital status is aggregated for the population aged 15 and more. Micro-level data was destroyed during the Second World War.

the women in childbearing years during the census may also contort the picture laid out by the child-woman ratio.

For these reasons, we use an alternative measure of fertility. The dependent variable is the *mean number of children of women born 1875–1894 who had married before their 35th birthday*. It is computed from the micro-data contained in the Family Register of Estonia − a sort of population register for the era between the two world wars, maintained from 1926–1944 (officially discontinued from 1949) (Teder, 1939). The Family Register is a complex dataset, which has been introduced in detail elsewhere (Gortfelder & Puur, 2020, Appendix 1). Here we present its most important features for the task at hand.

The Family Register makes it possible to compute a municipal-level mean number of children for women married in a precise cohort range, thus avoiding the outlined problems associated with the child-woman ratio. In this way, we follow previous research on the fertility transition that has also emphasized explaining levels of marital fertility (Coale & Watkins, 1986; Costa et al., 2021; Lee et al., 1994). The 35th birthday is chosen in order to exclude data for women who married after or at the very end of their reproductive years. We have chosen the cohorts born between 1875 and 1894 who gave birth from the 1890s to the 1940s, since most of the independent variables are from the early 1920s, and unfortunately not from earlier decades. Ideally, of course, we would like to involve earlier data. Still, the studied cohorts are the ones that experienced the second half of the fertility transition in Estonia (Gortfelder & Puur, 2019).

The Family Register does have some faults, which influence our study. The Register was maintained by the local governments on its inhabitants in single copies, meaning that in some municipalities, all or some register books were destroyed or went missing during the Second World War. The population of the municipalities for which the registers were completely destroyed or missing comprised 6.7% of the total population of the country (at the time of 1941 census). For many local governments with partially preserved registers, the number of women with intact records is small, and therefore the indicator of mean number of children computed from these are highly affected by small number variations.

For some municipalities, the information contained in the Register is also of low quality. As mentioned, the Register was kept from 1926 onwards. In principle, all demographic events (such as births of children) were supposed to have been included on the individual records even if these occurred before 1926.[5] The registration of all events had to be based on documentary evidence (birth, death, marriage records) kept by religious denominations, and from the 1920s, also local governments, not oral testimony. However, since church registers were event- and not individual-based, some events may have been unaccounted for in the Family Register.

[5] The individual records were opened to people alive and living in Estonia from 1926–1944. Thus, women who had died or emigrated beforehand were not included in the Register. This is possibly also a source of bias.

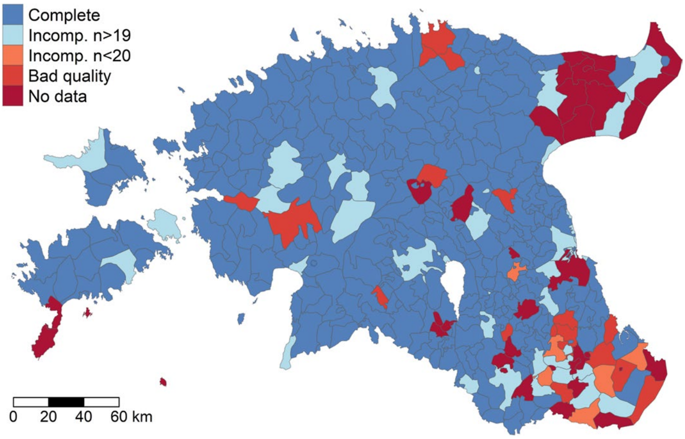

Fig. 2 Completeness and quality of the Family Register by municipality Source: Family Register of the Estonian Republic *Base map:* Municipality boundaries for Estonia in early twentieth century (Roosaare et al., 2000). The authors have made adjustments to some of the boundaries

Illegitimate children born and deceased before 1926 are a clear example.[6] For some municipalities, however, this particular problem seems to also influence legitimate births.

In addition, women are sorted into municipalities based on their final place of residence at the time of the late 1930s.[7] This means that an unknown percentage of women had some or all of their children elsewhere.

Finally, a serious issue with the Family Register is its lack of socio-economic and cultural variables, which makes it impossible to associate individual-level fertility behaviour with individual-level characteristics. This motivates the present study design in order to better understand the socio-economic and cultural factors related to fertility transition in Estonia.

Our units of analysis are 375 municipalities. Of these, 35 municipalities have no surviving records. Additionally, 5 municipalities have only below 20 surviving records (for the studied cohorts), hence we also treat these as missing. Finally, the records for 16 municipalities are judged to be of low quality. This judgement is made by (i) Comparing these to neighbouring municipalities, (ii) Looking at the level of child mortality[8] and (iii) Contrasting with the child-woman ratio derived

[6] This could be seen from the trends in the rate of illegitimacy and also from the comparison of infant mortality rates between legitimate and illegitimate children. From 1926, the illegitimacy rate, as well as the infant mortality rate for illegitimate children increases considerably.

[7] An opened individual record was not automatically transferred to a new municipality for the most part. This means that internal migration during the 1930s is also partly unregistered in the Family Register data. If the individual record was copied and sent to another municipality, however, the old record was closed with the explicitly stated reason. Thus, we can leave aside such records, and conclude that there are no duplicate records in the study.

[8] The under-registration of infant deaths is the primary concern with historic demographic data. If such deaths are under-registered, the number of children born is underestimated as well.

Table 1 Descriptive statistics on the municipalities *Source:* Family Register, 1922 census reports (Riigi Statistika Keskbüroo, 1924b), 1923 referendum (Riigi Statistika Keskbüroo, 1923), 1934 census reports (Riigi Statistika Keskbüroo, 1935)

Variables	Min	Max	Mean	SD	VIF
Dependent variable					
Mean number of children	2.3	5.6	3.7	0.6	
Demographic variables					
Child mortality before age 5 (%)	6.3	32.3	17.1	3.4	1.1
Population born in the same municipality (%)	6.7	97.6	57.8	17.7	2.4
Cultural variables					
Russians (%)	0.0	99.8	5.3	16.6	2.8
Non-Lutherans (%)	0.2	99.2	18.1	22.9	3.8
Against religious studies (%)	0.0	76.3	28.0	15.9	1.5
Educational variables					
Men with post-primary education (%)	0.0	34.2	6.1	4.3	2.2
Illiterate women (%)	4.0	77.3	14.0	10.8	4.2
Economic variables					
Economically active population (%)	21.5	64.3	39.0	6.8	1.9
Population dependent on agrarian sector (%)	1.5	98.6	78.1	21.2	2.2

Here the imputed values have been used

from the 1922 census results. Of these 16 municipalities, 10 have some register books destroyed or missing; this is possibly the primary reason for the low quality. Figure 2 shows the coverage and quality of information in the form of a map. Local governments depicted in blue are included in the study, with values directly derived from the register. Those marked in red are treated as missing, and for these the values are imputed. The problems of the Family Register are clearly concentrated in the north- and southeast due to heavier fighting there during the Second World War.

The partly incomplete and missing data means that we use imputation in 56 municipalities (15% of total). The imputation is done using the VIM package in R (Templ et al., 2021). To be more precise, we use the mean derived from the five most similar municipalities based on the variables derived from censuses used in the modelling (described below). In addition, the imputations use a variable for the county and a binary variable on whether or not we are dealing with a rural or urban municipality.

4.2 Independent Variables

We include nine independent variables in the study. The descriptive statistics is presented for all variables in Table 1. Most independent variables are based on published census results. The first of the demographic variables used in the analysis is the share of the population born in the same municipality. From a theoretical perspective, we can expect the traditional social ties and behaviours to be stronger in a place with a greater share of “rooted” people, and thus the fertility behaviour to also be more traditional. However, we should also note the existence of reverse causality here, given that areas with higher fertility have more children in the population, and thus a greater share of the population born in the same municipality, as we cannot distinguish population by age groups. Therefore, empirical results likely overestimate the strength of the relationship. This variable comes from the 1922 published census results (Riigi Statistika Keskbüroo, 1924b).

We include three cultural variables. The share of Russians measures the size of the Russian-speaking population. The share of non-Lutherans measures the share of religious minorities, and also includes the tiny share (0.3%) of people officially outside of any religious denominations. Both of these variables are derived from the 1922 census. On the basis of previous work, we would expect Russians to have considerably higher fertility than Estonians; the same is true for non-Lutherans, although less clearly (Anderson et al., 1979; Gortfelder & Jaadla, 2022). The third cultural variable is the share of votes cast against religious studies being included in the elementary school curriculum during the 1923 referendum. We use this measure as a proxy for secularisation and its spread in Estonia. The variable is based on the official published results (Riigi Statistika Keskbüroo, 1923). Based on previous studies (Blanc, 2021; Lesthaeghe, 1977), we would expect more secular areas to have earlier fertility modernisation and lower fertility. However, we should note that not all people voted against religious studies out of secular conviction—many non-Lutheran ethnic Estonians did so out of fear of the domination of the Lutheran Church (Gortfelder, 2021b).

In addition to cultural variables, we included two educational variables in the analysis, again from the 1922 census. One of these is derived for men and the other for women, to account for sex differences in educational expansion that would produce more variation in the measure. The share of men with post-primary education demonstrated more spatial variation across municipalities, as did the share of illiterate women. We expected to find, with both variables, that higher educational level is associated with lower fertility. Both educational variables are based on the population aged 10 and above.

We also include two variables related to the economic structure of the local population at the municipality level. Unfortunately, the published reports of 1922 census do not give economic information for rural municipalities, and all the relevant unpublished materials were destroyed during the Second World War. Thus, we use the 1934 census for economic variables (Riigi Statistika Keskbüroo, 1935). The first of the economic variables, the share of the economically active population, indicates the commercialization of the economic life in the municipality. Thus, a higher proportion in the economically active population indicates a greater development of market relations, greater wealth, but also greater economic inequality. We would expect there to be a negative relationship with marital fertility (Goldstein & Klüsener, 2014; Haines & Hacker, 2011). However, we should note that children are also counted among the economically inactive, which creates an issue with reverse causality, i.e., in areas with a greater share of children, there is also a greater share of the economically inactive population. This association pulls the relationship to the opposite, positive direction. The second economic variable, the share of the population dependent on the agrarian sector, expresses the importance of the traditional economic sector to the local economy. Here, the expectation is obvious—areas with more agrarian economies should have higher fertility (Brown & Guinnane, 2002).

Finally, we also derive one of the independent variables from the Family Register—the share of children born that died before age 5. Previous research has highlighted the importance between child mortality and fertility during the demographic transition (Reher, 1999; Gortfelder & Puur, 2020). Similarly, to the fertility measure used in the analysis, we impute the child mortality measure for municipalities without (enough) data or with low quality information.[9]

These nine independent variables are meant to capture different aspects that can be theoretically expected to have some impact on fertility. However, these variables are naturally somewhat correlated. In the last column in Table 1 we have included the variance inflation factor (VIF) to test the existence of dangerous levels of multicollinearity. As is shown, no variable shows very high values for this test. Still, one of these, the share of illiterate women, has a value above 4, which is moderately high. We have decided to include it given the theoretical importance of it and also the two variables with which it correlates the most (share of Russians and non-Lutherans), which are also relevant as discussed above.

4.3 Methods

In order to investigate spatial patterns in fertility and factors related to differences in fertility in Estonia, we employ two analytical approaches. First of all, we present a map of our main variable of interest − *mean number of children of women born 1875–1894* – for 375 municipalities in Estonia. We use Jenks natural breaks classification method for discretisation. In addition we estimate and map Local Indicators of Spatial Association (LISA) to identify spatial clusters of high and low fertility (Anselin, 1995). Local Moran's I identifies four different statistically significant spatial clusters: High-High (HH), Low-Low (LL), High-Low (HL), and Low–High (LH). The HH cluster is of municipalities with high mean number of children whose neighbouring municipalities also have high mean number of children. The LL is a cluster of low values. The HL and LH are outliers, meaning the very high fertility municipalities are neighbouring very low fertility areas or the opposite.

The standard way to analyse factors influencing levels of fertility with macro-data has for a long time been ordinary least squares (OLS) regression. This of course is problematic, given that one of the key assumptions of the model is that the units of analysis are independent of each other. With spatial data, due to the existence of neighbourhood effects, this assumption is for the most part not met (Fischer &

[9] While the mean number of children is computed on the basis of individual records for 88,004 women born 1875–1894, the child mortality variable is based on records for 75,480 women. The reason for this difference is that the full dates for birth and death for all children are required in order to compute this variable. Thus, we have excluded women with any missing or low-quality information regarding dates. We explore this issue further in the section on robustness checks.

Wang, 2011, pp. 7–11), meaning that there would be a spatial correlation in the error term. Also, it is assumed that the relationship between an independent and dependent variable is the same across the studied space, which is frequently incorrect (Matthews & Parker, 2013; Comber et al., 2022). In a more practical sense, it could mean that an inference made about an independent variable with OLS regression is not true; that is, the results may be biased.

Hence, in addition to OLS regression, we use a spatial Durbin model, which offers several advantages (Benassi & Carella, 2022; Sabater & Graham, 2019; Vitali et al, 2015; Yang et al, 2015). The spatial Durbin model includes in addition to the independent variables, the lagged dependent variable (as the spatial lag model) but also the lagged independent variables. This is relevant given that independent variables also have a spatial pattern. The spatial Durbin model allows to compute non-biased coefficients (Elhorst, 2010) and thus distinguish average direct and average indirect effects. A direct effect being the effect of changes in a given independent variable in a particular spatial unit on the dependent variable of the same unit, while the indirect effect works through covariation with neighbouring spatial units (Golgher & Voss, 2016). R's spatialreg package is used for the spatial analysis (Bivand et al., 2021).

In this article, we account for the interrelationship between neighbouring municipalities for both models by using the average value of the adjoining municipalities (sharing a border) to account for the spatial effect. Therefore, if a municipality has four adjoining neighbours, each contributes 25 percent to the average neighbourhood effect. The 375 spatial units under study have 2,047 spatial links with an average of 5.46 links.

Finally, it ought to be said that due to the nature of the data, the results are correlational in their nature, and we cannot thus conclusively prove that the statistical associations are also causal. Of course, the use of aggregated data holds the danger that conclusions drawn from this analysis may not be applicable at the individual level.

5 Results

5.1 Descriptive Overview of the Spatial Patterns of Fertility

Figure 3 shows the mean number of children for the studied cohorts of married women for the 375 municipalities under study. First, we will describe the spatial patterns in fertility (please consult Fig. 1 for Estonian geography). It is evident that there is considerable spatial variation in fertility in Estonia in the late 19th and early twentieth centuries. We find that the cohort fertility in urban areas was significantly lower than in most rural areas. This applies both for the capital industrialised Tallinn, which had the lowest level of fertility – 2.3 – but also other historic urban centres with varying degrees of industrialisation (Kuressaare, Haapsalu, Pärnu, Viljandi, Valga, Rakvere, Narva, Tartu, Võru) and smaller and newer municipalities that became urban during industrialisation and urbanisation. Among the twenty municipalities with the lowest cohort fertility, all but four are urban.

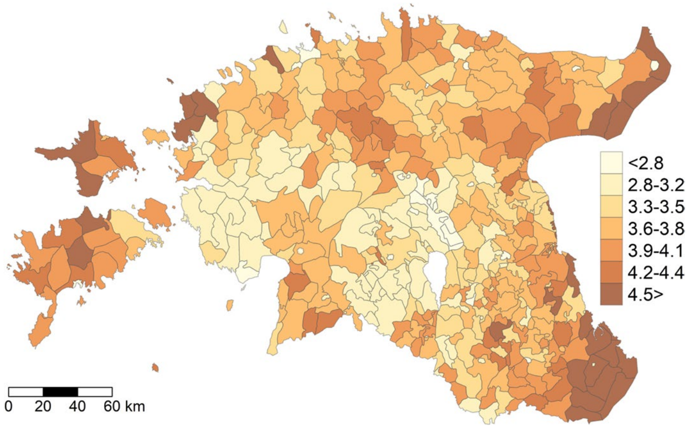

Fig. 3 Mean number of children by municipality for married women born 1875–1894. *Note:* Here the imputed values have been used. Source: Same as in Fig. 2. *Base map:* Same as in Fig. 2

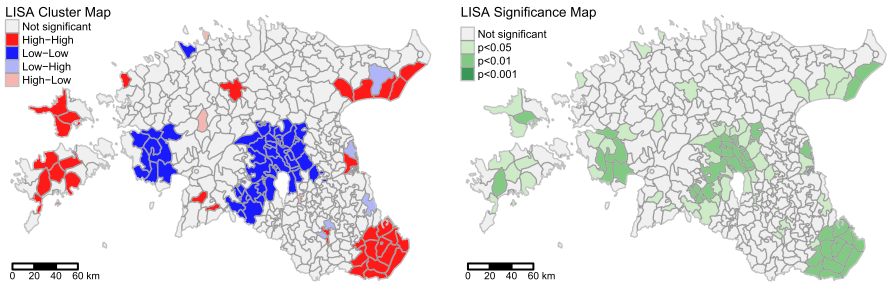

Fig. 4 Spatial clustering of mean number of children by municipality for married women born 1875–1894 in Estonia, LISA cluster and significance maps. *Note:* Here the imputed values have been used. Source: Same as in Fig. 2. *Base map:* Same as in Fig. 2

At the same time, significant differences in fertility levels can be seen also in the mostly rural areas. The LISA analysis shown on Fig. 4 demonstrates clearly the clusters of low fertility or coldspots. Two rural areas especially stand out with considerably lower fertility. The first includes Viljandi county and the southeastern part of Pärnu county in southern Estonia. The second includes the western part of Pärnu county and the southern part of Lääne county on the western coast of mainland Estonia. The first of these areas was at the forefront of modernisation in other spheres of life as well (agricultural innovation, market-orientation, modern mentality, national identity). The second, however, is not linked to early modernisation in any other field but usually seen as a poor and backward periphery.

With respect to high fertility areas or hotspots on Fig. 4, it is clear that fertility was much higher in the eastern border areas. This is also the region where the highest mean number of children in one of the municipalities is measured – 5.6. On the other side of the country, the western islands also had higher mean

Table 2 Regression results for the OLS and spatial Durbin models *Source:* Family Register, 1922 census reports (Riigi Statistika Keskbüroo, 1924b), 1923 referendum (Riigi Statistika Keskbüroo, 1923), 1934 census reports (Riigi Statistika Keskbüroo, 1935)

Dependent variable: cohort fertility for women born 1875–1894 and married before 35th birthday

Variables	OLS		Spatial Durbin			
	Coef	*p*	Coef	*p*	Lag coef	Lag p
Intercept	3.2440	0.000	1.6643	0.005		
Demographic variables						
Child mortality before age 5 (%)	0.0255	0.000	0.0200	0.000	−0.0022	0.835
Population born in the same municipality (%)	0.0051	0.004	0.0014	0.463	0.0038	0.235
Cultural variables						
Russians (%)	0.0128	0.000	0.0119	0.000	-0.0048	0.185
Non-Lutherans (%)	−0.0042	0.026	−0.0006	0.769	−0.0045	0.174
Against religious studies (%)	−0.0002	0.879	−0.0006	0.608	0.0032	0.248
Educational variables						
Men with post-primary education (%)	−0.0179	0.010	−0.0206	0.002	0.0189	0.131
Illiterate women (%)	0.0049	0.204	0.0088	0.059	−0.0074	0.249
Economic variables						
Economically active population (%)	−0.0164	0.000	−0.0111	0.003	−0.0044	0.518
Population dependent on agrarian sector (%)	0.0051	0.000	0.0070	0.000	−0.0049	0.103
ρ (spatial lag parameter)			0.4971	0.000		
Moran's *I*	0.2975	0.000	−0.0290	0.786		
(Nagelkerke) R^2	0.5242		0.6273			
AIC	375.22		312.82			

number of children. On the whole fertility, was also higher in the northern part of the country.

Both Table 1 and Fig. 3 show that the scale of the difference in fertility levels was very high during the fertility transition. The gap between the lowest (2.3) and highest (5.6) is at 100%.[10] From Fig. 3, it is clear that there is considerable spatial correlation in the mean number of children. To be more precise, Moran's *I* value is 0.40 (p-value < 0.000).

5.2 Main model Results

Table 2 gives the results of the OLS and spatial Durbin models. Coefficients for the OLS model in Table 2 with a positive value indicate that the independent variable in question is associated with an increase in the mean number of children (for women married before their 35[th] birthday), while coefficients with a negative value indicate

[10] The maximum and minimum values for mean number of children for women aged 35–49 recorded during the 2011 census were 1.47 and 2.9. The standard deviation was 0.27. Number of municipalities was 226.

Table 3 Decomposition estimates of the direct and indirect effects of independent variables *Source:* Family Register, 1922 census reports (Riigi Statistika Keskbüroo, 1924b), 1923 referendum (Riigi Statistika Keskbüroo, 1923), 1934 census reports (Riigi Statistika Keskbüroo, 1935)

Dependent variable: cohort fertility for women born 1875–1894 and married before 35th birthday

Variables	Direct		Indirect		Total	
	Mean	*p*	Mean	*p*	Mean	*p*
Demographic variables						
Child mortality before age 5 (%)	0.0210	0.000	0.0145	0.419	0.0354	0.084
Population born in the same municipality (%)	0.0019	0.289	0.0083	0.128	0.0102	0.078
Cultural variables						
Russians (%)	0.0121	0.000	0.0020	0.698	0.0140	0.020
Non-Lutherans (%)	−0.0012	0.485	−0.0090	0.087	−0.0102	0.039
Against religious studies (%)	−0.0006	0.722	0.0051	0.239	0.0045	0.314
Educational variables						
Men with post-primary education (%)	−0.0196	0.004	0.0161	0.510	−0.0034	0.860
Illiterate women (%)	0.0084	0.050	−0.0057	0.529	0.0027	0.828
Economic variables						
Economically active population (%)	−0.0123	0.001	−0.0184	0.152	−0.0307	0.021
Population dependent on agrarian sector (%)	0.0069	0.000	−0.0026	0.628	0.0043	0.459

the opposite. The numeric value shows the effect of a one-unit change in the independent variable. In this study, given that all independent variables are in percentages, this would mean a one percentage point increase. For the spatial Durbin model the coefficients do not allow for a similar interpretation and this is why Table 3 gives the marginal effects in which the direct effect allows for a similar interpretation.

Let us first begin at the bottom rows of the table. The Moran's *I* coefficients in Table 2 are calculated from the model residuals. The Moran's *I* indicates the presence of spatial autocorrelation, and thus bias in the model results. It is clear that the OLS model residuals do have some spatial autocorrelation with a statistically significant coefficient of 0.298. This is not surprising due to the reasons given above. For the spatial Durbin model, however, no spatial autocorrelation remains in the residuals, given that it accounts for the existence of neighbourhood effects. The spatial lag parameter has a large and statistically significant coefficient, as can be seen from Table 2, again highlighting the considerable spatial dependence in levels of fertility between neighbouring municipalities.

The superiority of the Durbin model can also be observed from the coefficient of determination and the Akaike Information Criterion (AIC) values at the very end of Table 2. These give a numeric value to the fit of the model, or its explanatory power. Given this comparison, we shall discuss the results for specific variables only with Table 3, which gives the direct, indirect and total effects of the variables based on the Durbin model.[11] As can be seen, the variables of interest have generally much stronger direct effects, while the indirect effects are mostly statistically not significant suggesting that impacts of the variables on fertility are mostly constrained in the same municipality and do not work through neighbouring municipalities.

We start with the demographic variables. The results show that a greater share of children deceased before age 5 correlates positively with a higher number of children. The direct effect of this variable is the biggest with a one percentage point increase in the percentage of children deceased in a municipality increasing the number of children by 0.02 children – a 10 percentage point increase would thus mean an effect of 0.2 children. This underlines the importance of earlier declines in child mortality, which gave parents motivation to curtail their childbearing. There is no indirect effect of child mortality (through neighbouring municipalities). The share of the population that was born in the same municipality has no direct or indirect effect. Although, the indirect effect is close to being significant and the sum of the two is significant at the level 0.1 and shows a positive relationship with the dependent variable. This hints that the share of "rooted" individuals may have impacted fertility levels in neighbouring municipalities.

Of the three cultural variables, only the share of Russians has a significant direct effect with a one percentage point increase in the share of Russian population in a municipality increasing the mean cohort fertility by 0.01 children. This in unsurprising, considering that the eastern border areas showed the highest mean number of children, almost all of these municipalities had also a majority Russian population. At the same time the indirect spillover effect of Russians from neighbouring municipalities has no effect on the dependent variable. For the non-Lutherans, there is no direct effect, while there is a weak negative indirect and total effect showing that a higher share of non-Lutherans in adjacent municipalities is associated with small reduction in municipality-level fertility. Keeping in mind that the models control for the ethnic makeup, the variable for non-Lutherans shows the result for Estonian non-Lutherans. In a simple (one variable) regression model, the effects of the share of religious minorities are positive. The share of votes cast against religious studies in a referendum—our secularisation proxy—is consistently not significant. This indicates that secularisation itself was not important for determining fertility behaviour, and the significant negative effect in simple regression models is largely explained by other variables, mainly the two educational variables. This is surprising considering the results for other countries discussed above.

Our results indicate that the direct effect of both educational variables is as theoretically expected – better educational levels are associated with lower fertility. The effect for the share of men with post-primary education is the second biggest in absolute value indicating that a one percentage point increase in the share of better educated men is associated with 0.02 reduction in the mean number of children. To a large extent this result is driven by urban areas, which almost universally have a greater share of men with post-primary education than the surrounding rural areas.

[11] These are computed based on 1000 simulations with the impacts() command of the spatialreg package.

Still, the same relationship is also evident in the countryside. The direct effect for female illiteracy is a bit under 0.01 children, which is mostly explained by the fact that in the low-fertility area of western Pärnu and southern Lääne counties, the share of illiterate women is higher than in most parts of the (majority Estonian) country. There are no statistically significant indirect effects of both educational variables.

Finally, the two economic variables show expected direct effects. The share of the economically active population shows that a higher degree of market labour in a municipality is linked with lower fertility. This relationship prevails even though, as noted, there exists a reverse causality, which pulls the relationship in the other direction. Thus, with a better measure the effect of commercialism ought to be much greater. A higher share of the population dependent on the agricultural sector also is clearly linked with more traditional fertility behaviour in the same municipality. For the indirect effects through neighbouring municipalities, we can see an almost statistically significant negative effect for the share of economically active population, which would probably be significant with a better measure, and thus convincingly show the relevance of the economic profile of neighbouring municipalities for fertility levels.

5.3 Sensitivity Checks

Next, we report the results of a number of sensitivity checks. All the regression tables are presented in the online appendices.

First, we address the question of how much the outcomes would change if we chose the cohorts of women differently. Appendix 1 shows the results for the analysis done with cohorts born 1870–1889 and 1880–1899. The change is minuscule and does not reverse any of the main conclusions. For the cohorts 1870–1889 the share of born in the same municipality has a statistically significant direct effect (unlike on the main results). For cohorts born 1880—1899 the same holds for the secularisation variable. We should note that we would not want to study cohorts born before 1870, keeping in mind that most independent variables come from the 1920s. Also, we could not include cohorts born after 1899, since the end of Family Register in mid 1940s would mean that we would not be able observe women at the end of their fertile years.

Second, we specified the models in which we excluded child mortality measures, as we highlighted earlier that the child mortality variable is of lower quality than the fertility variable due to limits regarding the availability of data in the Family Register. Thus, we also ran the models without the child mortality variable. Appendix 2 provides these results, and the outcomes of the analysis are unmodified.

Third, our main analysis uses imputed estimates for 15% of districts included in the models. This is a rather high proportion. Hence, as a sensitivity test, we ran an additional OLS model with 317 municipalities for which we have not used imputation. Appendix 3 gives these results and again, our findings remain stable.

Fourth, we also explored a model which included the mean age at first marriage computed from the Family Register. The fertility transition mostly concerns the emergence and spread of stopping behaviour (Gortfelder & Puur, 2019; Knodel, 1987). However, in different municipalities, the mean age at first birth (which is closely tied with the mean age at first birth) can differ in the pre-transition era. This means that comparing the mean number of children, we would not take into account the relative decrease in fertility in communities with earlier marriage. Appendix 4 shows that the main regression results are robust to the inclusion of this variable.

Fifth, we compare the results of the spatial Durbin model to the multiscale geographically-weighted regression (MG-GWR) (Comber et al., 2022). This is done in order to see if a local regression model is better in terms of fit and interpretation. In terms of fit MS-GWR is an improvement on the spatial Durbin model. However, this is due to allowing the intercept to vary. In terms of the independent variables, we do not see any extra benefit with respect to the spatial Durbin model, since six of the nine independent variables are global, one that shows variance is statistically not significant and mapping the local coefficients if the remaining two (share economically active and share dependent on the agrarian sector) does not allow for an easy interpretation with existing knowledge about Estonian history.

Sixth and finally, in Appendix 6 we present models in which we exchanged our dependent variable with the child-woman ratio (CWR) measured during the 1922 census. This is, we underline, a general fertility measure, and is thus sensitive to variation in the share remaining unmarried. Here there are noteworthy changes for two variables. The secularisation variable becomes statistically significant in the OLS model as does the total effect from the Durbin model with a theoretically expected minus sign, indicating that a higher share of votes against religious studies is associated with lower fertility. However, the strength of this influence is constrained compared to other variables. Secondly, the share of the population dependent on the agrarian sector changes its sign to a theoretically unexpected negative sign in the OLS model, however the marginal effects derived from the Durbin model are statistically not significant. We believe this to be an artefact, and do not interpret this.

6 Discussion and Conclusion

In this paper we have used a combination of multiple data sources to explore the determinants of fertility and spatial variation in fertility in Estonia during the second half of the fertility transition. Our findings show that there was significant spatial variation and clustering of fertility across municipalities throughout the transition process, even in a country as small as Estonia. As expected, lower levels of fertility were observed in urban areas, but also rural regions in the southern (Viljandi and southeastern Pärnu counties) and western coastal mainland (Lääne and western Pärnu counties) areas of the country showed signs of lower fertility and earlier onset of fertility transition. The municipalities further to the east and on the western islands lagged behind in this process of demographic modernisation.

The spatial variation in fertility is not easily explained by one or two factors, but rather, a combination of spatial, economic and sociocultural determinants is crucial to understand the patterns of variation. In our analysis, these three different dimensions explain over half of the variation in cohort fertility. In line with the Princeton Project (Coale & Watkins, 1986), we find that cultural-linguistic boundaries are important for regional fertility differences in the Estonian context with a clear line between majority Estonian and majority Russian municipalities. The findings clearly underline the relevance of higher educational levels in decreasing fertility and this both for men and women and in terms of very basic education (literacy) as well as post-primary education.

Our findings are also consistent with theory and empirics in terms of economic factors influencing fertility (Becker, 1960; Cleland & Wilson, 1987; Dribe, 2009; Goldstein & Klüsener, 2014; Guinnane, 2011; Haines & Hacker, 2011). First, we find a negative relationship between labour market activity and fertility, indicating that the loss of the economic significance of the family is associated with a smaller family size. Second, we find a positive relationship between a greater importance of the traditional economic sector (agriculture) and fertility, which shows that urban living arrangements constrained the amount of children that people were having.

However, our analysis fails to support that secularisation, measured by the share of votes cast against religious studies, influenced differences in cohort fertility during fertility transition in Estonia. It is possible that the timing of mass secularisation compared in Estonia to the onset of fertility transition was misaligned, which was not the case in the French-speaking areas of Europe (Blanc, 2021; Lesthaeghe, 1977). The events surrounding the revolution of 1905 are seen as a crucial moment for early secularisation in Estonia (although this remains an understudied topic). This suggests that the process of secularisation occurred too late in Estonia compared to the start of the fertility transition (few decades earlier) to be significant in explaining spatial variations in fertility. Future research and individual-level case study based on a parish or two similar to Hallberg (2013) may give us more insight.

Our results on Estonia provide further support that spatial relationships played an important role in historical fertility transitions. We find that there was clear spatial dependence of neighbouring municipalities influencing each other's fertility levels. This means high fertility in neighbouring municipalities is related to higher fertility within a given municipality or surrounding low fertility related to low fertility within a given spatial unit. The use of the spatial Durbin model allowed us also to distinguish between the direct as well as indirect effects of the independent variables. These results show that direct effects of most variables in our models were more important than spillovers, which means that the effects of these variables (if any) are confined to the municipality itself and do not work through surrounding municipalities.

There are a few limitations to consider. First, due to the lack of suitable data, we work with a cross-sectional study design that cannot conclusively prove causal relationships. Second, the dependent variable used in this study has been constructed using data that does suffer from issues of availability and quality, and the only other alternative fertility measure, the child-woman ratio, is comparatively primitive, and only relevant to general and not marital fertility. Third, as pointed out, the variables based on published census reports are measured during the second half of the fertility transition in Estonia due to the lack of earlier available data. Thus, this could mean that the statistical relationships between marital fertility and economic and socio-cultural factors may have been different at the starting point of the fertility transition.

Nonetheless, this study highlights the advantages of using data on fine spatial scale even in a country as small as Estonia to study the patterns and determinants of the fertility transition. Overall, our findings contribute to the literature on fertility transitions in the late 19th and early twentieth century and highlight the importance of educational attainment, cultural-linguistic boundaries and economic factors in understanding patterns of fertility variation.

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Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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