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Marital fertility decline and child mortality in the Sardinian longevity Blue Zone

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Abstract

Several authors have studied the late fertility transition in Sardinia, which did not start until the 1950s. This contribution aims to investigate the association between the decline in marital fertility and the fall in infant and child mortality. We use individual data to undertake classical family reconstruction starting from the mid-19th century for the population of two Sardinian villages, Villagrande Strisailli and Seulo, which we have previously studied for their remarkable longevity. Our results indicate that in this population, there were very few signs of fertility decline prior to 1920, and fertility decreased only gradually before 1950, but that the decline in fertility accelerated thereafter. We also found that infant and child mortality decreased slightly between the two world wars, and did not decline substantially until after the Second World War. The question arises as to whether these two transitions were associated, and, if they were, which one preceded the other. Our results suggest that there was some degree of synchronisation, with more pronounced changes beginning in the 1950s. We found that this association cannot simply be explained by a causal relationship based on altered demographic behaviour. Substantial socio-economic changes that began between the two world wars and developed fully in the 1950s might have caused both fertility and mortality declines within a traditional society that was undergoing a transition to adapt to the modern world.

Keywords: marital fertility; infant mortality; child mortality; demographic transition; family reconstruction; Sardinia; longevity blue zone

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1 Introduction

Although the historical decline in fertility has been extensively studied since the 1970s, particularly in Europe after the results of the European Fertility Project became available, it is still an attractive research topic, as more detailed data are emerging, and existing theories can increasingly be tested among specific populations (Brown and Guinnane 2018; Fernihough and McGovern 2014; Reher et al. 2017; van Poppel et al. 2012). Our interest here is in the long-term fertility decline among a population who were somewhat isolated and followed a traditional lifestyle characterised by high levels of fertility up to the mid-20th century. In this contribution, we study two villages in Sardinia – Seulo and Villagrande Strisaili (hereafter referred to Villagrande) – whose inhabitants are remarkable for their exceptional longevity (Poulain et al. 2004, 2011). The availability of historical aggregated and individual genealogical data for these villages that have been collected since the first half of the 19th century enable us to study the long-term decline in fertility in this population over more than a century. The fertility transition in the mountainous areas of Sardinia where these villages are situated occurred later than it did among other populations in Italy and in Europe in general. Under the auspices of the European Fertility Project developed in Princeton, Livi-Bacci (1977) found that for all of Italy, the Coale's Index of marital fertility I_g declined the latest in the mountainous province of Nuoro, where families with six or more children were still common until the 1950s. Furthermore, the historical trends in infant and child mortality in this region differed from those observed in other parts of Italy. The decrease in mortality began later in Sardinia (Gatti 2002), although lower levels had already been observed at the beginning of the previous century. Our interest here lies in investigating the questions of whether and, if so, how these two relatively late and synchronous fertility and mortality declines were associated, and whether one preceded the other. Our study might provide evidence of a causality in this association.

2 Background and research questions

The relationship between mortality and fertility has been a topic of interest since the beginnings of population research. The main focus of this research has been on how infant and child mortality has affected the reproductive behaviour of mothers (Knodel 1988). It was argued that among pre-transitional populations, the relationship between fertility and mortality resulted in low levels of natural increase in the population. Since the demographic transition theory was formulated, the decline in fertility has been attributed to four different factors: (i) the decline in mortality, particularly child mortality, which reduces uncertainty about the survival of children; (ii) fewer interruptions of breastfeeding due to the early deaths of children, which tends to increase the intervals between births, as suggested by Knodel (1988); (iii) the desire of couples to have a given number of surviving

children – the so-called "replacement factor" (Schultz 1969); and (iv) sequential decisions related to the birth of the next child depending on the outcome of each pregnancy (O'Hara 1972). In general, the theoretical perspective assumes that there is a positive association between marital fertility and infant mortality levels; i.e., that higher infant mortality is associated with higher fertility, and *vice versa*. This association has been studied at both the aggregate (community) and the family levels.

Most studies on this topic have found that at the community level, the decrease in infant and child mortality and the decline in marital fertility are indeed linked, or are, at least, associated. Nevertheless, there is no consensus about the causality of this association – i.e., about whether the decrease in infant and child mortality preceded or followed the decline in marital fertility. Schultz (1969) assumed that an established pattern of childhood mortality at the community level would influence couples' lifetime reproductive behaviour, leading them to seek to compensate for the expected death of their offspring. The duration of breastfeeding might help to explain why higher fertility could result from higher mortality, since the death of an infant would eliminate the contraceptive effect of breastfeeding. In addition to the reduction in the period of post-partum infertility, the possible deterrent to intercourse posed by the presence of an infant would be removed. By contrast, Knodel (1988) found that a decline in fertility usually preceded a decrease in infant mortality. Similarly, Reves (1985) hypothesised that it was the decline in fertility that caused the decrease in infant mortality resulting from infections. This argument is important, because it is inconsistent with the notion that the decline in infant mortality initiated the decline in fertility. From this perspective, fertility change was not driven by the decline in infant mortality, but it may have been a component of the broader infant mortality transition. The results of recent studies do not reflect a systematic agreement with any of these theories. In light of more recent results, some of which are controversial, it is not clear in what order these changes appeared, or whether they were interrelated (Brown and Guinnane 2018; Fernihough and McGovern 2014). The processes that have occurred and are still occurring in different geographic settings and among various historical and contemporary populations suggest that there has been more diversity in the patterns of change than the theory of the fertility transition would predict. Thus, the relationship between the decline in fertility and the decrease in infant mortality is disputed by scholars who have, for example, argued it may be more complex than earlier theories predicted, and could vary between societies (Hirschman 1994). Some authors have argued that broader concepts or a kind of community understanding of how many children are likely to survive to adulthood must be operating in addition to individual choice (Lesthaeghe 1980; Sánchez-Barricarte 2018). Knodel (1988) has observed that a combination of educational factors, social and religious norms, and the availability of contraceptive methods operated indirectly (and presumably unconsciously) to adjust the level of community fertility to the level of community mortality. The adaptation to new forms of behaviour involves processes of innovation and diffusion that are reliant on three preconditions

for behavioural change to occur: *readiness, willingness* and *ability* (Coale 1973 as cited in Lesthaeghe and Vanderhoeft 2001). Recent research has repeatedly shown that in addition to the decrease in childhood mortality, increases in levels of education and economic development played important roles in the historical decline in fertility (Sánchez-Barricarte 2017, 2018). While the economic context clearly contributed to the decrease in child mortality, economic growth was also consistent with a decline in fertility (Brown and Guinnane 2018). Cultural and social factors conditioned the reproductive behaviour of couples, but mortality could also be affected by (temporal) socio-economic and political conditions.

At the family level, low child mortality might have encouraged a mother to stop bearing children before she became biologically sterile, whereas the death of several children could have caused her to follow the traditional pattern of uncontrolled fertility. It is, however, also possible that the death of several children would have discouraged a couple from continuing to have children in order to avoid additional disappointment (Knodel 1988). Moreover, children who were born later in the sibling order had a higher mortality risk than those who were born earlier (Modin 2002), and the death of a higher parity child could indicate that the mother had a physical limitation that prevented her from continuing to bear children. It was thus assumed that the parents' decisions about whether to have another child were sequential, and depended on the outcomes of previous childbirths, rather than on an intention to have a certain number of surviving children (Williams 1977). While the discussion about the association between fertility decisions and child deaths has not reached a consensus, an association has been observed between the loss of a child and the birth interval (Schultz 1969; Plana-Ripoll et al. 2018). If a decline in fertility could be interpreted as a decline in the total number of surviving children a woman or a couple wanted to have, a decrease in infant and child mortality should have lowered the fertility level. It appears, however, that the effect of low mortality on couples' decisions to reduce the number of subsequent pregnancies does not adequately explain why couples gradually reduced the number of children they had to replacement level during the fertility transition. Moreover, for the population as a whole, having smaller families could have resulted in the same or even higher levels of fertility, as happened during the post-war baby boom (Preston 1976).

The association between fertility outcomes and child mortality has been mostly studied for the early period of the European demographic transition. Given that both fertility and infant and child mortality decreased relatively late in Sardinia – gradually after the First World War, and more substantially after the Second World War – this study aims to provide new insights into this topic by examining both aggregated and individual data obtained through family reconstruction.

We seek to answer the following research questions regarding a possible association between the decline in fertility and the decrease in infant and child mortality:

- At an aggregate level, were the declines in marital fertility and the falls in infant and child mortality synchronous? Is there any indication based on the aggregated data that one of these two trends preceded the other, which could indicate a causal effect?

- The next question is addressed using individual data to analyse mothers' fertility behaviour in relation to the survival of their children. We study whether the loss of a child due to stillbirth or death during the first year of life increased the probability of having another child. Such an effect might be seen as reflecting an intention to replace the lost child.
- When another child was born after the death of a sibling, we examine whether this birth affected the length of the next birth interval. If the interval was shorter than the other intervals, it could be seen as an implicit mechanism for replacing the lost child that would tend to increase the total number of children the mother has.
- From a different perspective, we will investigate whether maintaining the same level of the net reproduction rate, and, more specifically, the number of children surviving beyond age five, might explain the long-term historical equilibrium between mortality and fertility, as suggested by Cleland (2001).
- In addition, we aim to analyse whether the survival of children correlates with mothers having a higher number of children or shorter birth intervals.
- Moreover, with regard to the two villages under study, we will discuss the possibility that a common socio-economic and cultural context contributed simultaneously to the sharp decrease in fertility and the steep decline in infant and child mortality.

3 The population and data sources

Past research has revealed that the fertility transition occurred later in Sardinia than in other parts of Europe. At the beginning of the 20th century, high levels of marital fertility were reported on the island (Livi-Bacci 1977; Bernardi and Oppo 2007). As late as in the 1950s, the province of Nuoro in the mountainous region of Sardinia exhibited the highest levels of Coale's Index of marital fertility (Ig) among all of the Italian provinces observed during the fertility transition. It has also been reported that in some inland areas of the island, mostly in the province of Nuoro, the population has been characterised by exceptional longevity (Poulain et al. 2004) and late fertility (Astolfi et al. 2007, 2009) – and that there could be an interesting linkage between these two trends (Poulain et al. 2016).

Two villages, Seulo and Villagrande, were selected for this study on the basis of the authors' interest and the findings from earlier research conducted in these communities on the reasons for their exceptional longevity (Poulain et al. 2004). In addition to being known for their longevity, both villages are located in an area where fertility and mortality transitions have tended to occur much later than they have in most other Western populations (Livi-Bacci 1977; Bernardi and Oppo 2007; Poulain et al. 2016). Seulo and Villagrande are situated more than 700 meters above sea level on the southern slopes of Punta La Marmora, the highest mountain in Sardinia at an altitude of 1,834 meters.

In 2018, 3,186 inhabitants were living in Villagrande and 835 were living in Seulo (ISTAT-*Istituto Nazionale di Statistica*). The first general census of the population of a unified Italy in 1861 recorded 1,251 inhabitants in Villagrande and 714 inhabitants in Seulo (ISTAT). The population grew continuously from 1861 to the second half of the 20th century, reaching a maximum of 1,772 in Seulo in 1961 and of 4,029 in Villagrande in 1971.

Historically, the main economic activity in both villages was sheep farming on the surrounding slopes, and also on the coastal plain in winter and higher in the mountains in summer. These cycles of transhumance took men away from their village for most of the year (Salaris 2009). In general, the village constituted a self-sufficient economic system in which each family member contributed to the household. The men were mainly responsible for raising animals and providing the family with food and raw materials (Salzman 1998). The women were primarily responsible for keeping the house, planting and maintaining terraced gardens near the house or surrounding the village, gathering firewood and weaving. The children in the family worked alongside their parents. It was a matriarchal society characterised by a high level of endogamy: more than 80% of marriages occurred between people of the same village, often between distant relatives (Cannas 2007).

The regional economy expanded in the 1950s when better roads and communication opened both villages to the external world. Simultaneous improvements occurred in health services, the pension system, education and social security. Even though this region was among the poorest on the island until the 1960s, these economic improvements rapidly raised the welfare standards of the populations of both villages nearly to the average for Italy. One of the outcomes of these developments was that most women started having their births in maternity hospitals in neighbouring towns.

Ascertaining the drivers of a decline in fertility and its possible association with a decrease in infant and child mortality is often hindered by a lack of suitable data; e.g., individual longitudinal data covering a long period of time. While a number of studies have been undertaken to collect such data by using the family reconstruction technique, not all were able to cover sufficiently long periods of time (Sánchez-Barricarte 2018). The present analysis uses data collected by classical family reconstruction that span two centuries. More precisely, the database covers the whole population for a period from the beginning of the 19th century to 1 January 2018, including births that occurred in the earliest years and deaths or survival information from the latest years. The municipalities of the two villages supported the collection of the demographic genealogical data. The main data source we used was a system of civil records of demographic events that was first introduced in Italy in 1866. The records from this source were checked against parish records of marriages, burials and baptisms for the earliest years of civil registration (from 1866 to 1900). No significant differences were found between the records from these data sources. In addition, to ensure that we were including all births, we consulted the population register (*anagrafe*), which was initiated at the end of the 19th century; and the 1951 census enumeration and confirmation

lists. We also examined the family histories of women born between 1840 and 1989 in Villagrande and Seulo. The investigation involved 3,006 married women, 2,582 of whom had at least one child. Among this group, 47 women remarried and consequently appeared more than once in this analysis.

The following criteria were used to select the married couples for whom a completed fertility history was constructed:

- The woman or her husband were born in Villagrande or Seulo, and the woman's date of birth was well-documented and occurred between 1840 and 1989.
- Both spouses survived and lived in Villagrande or Seulo until the woman reached the age of 45, or they were younger and were still living in one of the villages on 1 January 2018.
- The couple did not emigrate during their reproductive period; therefore, all of their children were born in the two villages, and their dates of birth were identified.

In total, we were able to compile complete, well-documented fertility histories for 2,353 couples in which both spouses survived up to the wife's 45th birthday. These women gave birth to 10,250 children from 1858 to 2017. The level of completeness of the information on the demographic events of each individual was high, as the date of death or evidence of survival was found for all but 85 new-borns.

4 Results

4.1 Trends in marital fertility

Our first step was to consider the so-called natural fertility period. To do so, we selected 749 women born from 1840 to 1890 who had married before 1920. We computed the marital fertility rates for 583 women in couples in which both spouses survived until the wife reached age 45 and who had at least one child. A total of 3,030 children were born to these women. Women who remarried after the death of their first husband were excluded. In these birth cohorts, 38 children born as "illegitimate" were also excluded, even if they had been recognised by their father. The calculation of marital fertility rates takes into account 71 married women who did not give birth to a child in their marriage. Childlessness among married couples during the natural fertility period was determined to be 12.2%, which is higher than the 7.1% rate found in Alghero by Breschi et al. (2009b) and the 10% rate reported in Casalguidi by Manfredini et al. (2009). This relatively high level of childlessness might be explained by the presence of a significant number of women who married a widowed brother-in-law close to the end of their fertile lifespan in order to care for the children of their deceased sister. Marital fertility rates in Villagrande and Seulo during the period of the natural fertility regime are compared with similar data from Hutterites and in Alghero in Table 1.

Table 1:
Marital fertility rates for completed families under a natural fertility regime in Villagrande and Seulo, for Hutterites and in Alghero

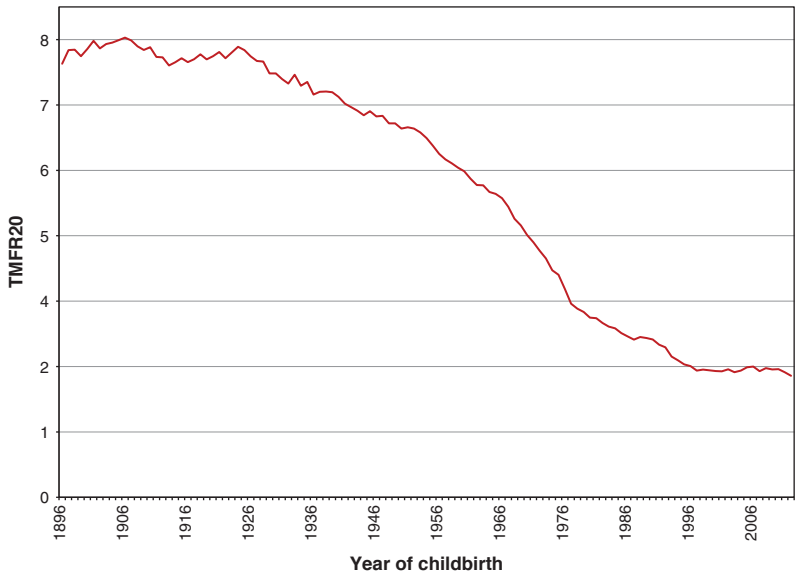
Age groups of mothers	Marital fertility in Seulo and Villagrande, women born 1840–1890*	Marital fertility for Hutterites, marriages 1921–1930 (Tietze 1957)	Ratio between Sardinian and Hutterite fertility rates (%)	Marital fertility in Alghero, marriages 1866–1885 (Breschi et al. 2009b)
Number of women	583	204		434
20–24	0.450	0.550	81.7	0.383
25–29	0.400	0.502	79.8	0.362
30–34	0.357	0.447	80.0	0.325
35–39	0.298	0.406	73.5	0.253
40–44	0.178	0.222	80.0	0.134
45–49	0.038	0.061	61.9	0.015
TMFR20	**8.61**	**10.94**	**78.7**	**7.36**
TMFR25	**6.36**	**8.19**	**77.7**	**5.44**

Note: *Corresponds to marriages occurring between 1865 and 1920.

The level of marital fertility found in Villagrande and Seulo was close to the highest figures computed by researchers who used the same family reconstruction method for other 19th-century villages in Italy. These Italian results range between 6.6 and 8.6 for the TMFR20 (total marital fertility rate starting at age 20) and 4.6 and 6.2 for the TMFR25 (total marital fertility rate starting at age 25) (Livi-Bacci 1977; Breschi et al. 2009a). Both rates were lower in Alghero (TMFR20 of 7.36 and TMFR25 of 5.44) (Breschi et al. 2009b).

As Table 1 shows, the ratio between the marital fertility rates for the same age groups of mothers in Seulo and Villagrande and in the Hutterite population does not vary greatly. The rates in Seulo and Villagrande are about one-fifth lower, which could be explained by the longer birth intervals in Seulo and Villagrande than in the Hutterite population (an average of 34.1 months, compared to 25.4 months among the Hutterites); and by the traditionally lengthy breastfeeding period in Sardinia, which was already mentioned by Coletti in 1908. Accordingly, for a comparable reproductive period, the expected number of children among mothers in the two analysed villages was systematically around one-fourth lower than it was among the Hutterites. Based on this result and the availability of data on marital fertility for each year of age of the mothers, we were able to determine the level of fertility under a natural fertility regime, and to assess the long-term trend in marital fertility for the two villages during the 20th-century fertility transition.

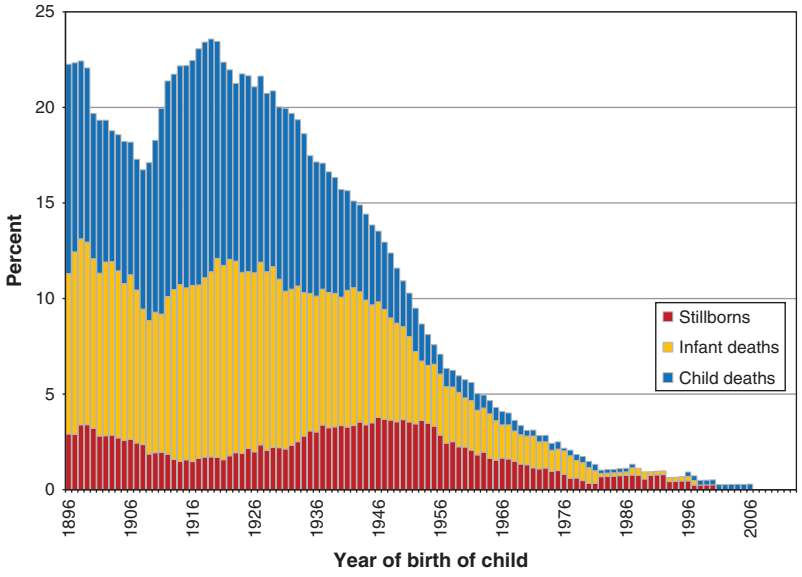
Figure 1:
Marital fertility in Seulo and Villagrande: TMFR20 by year of childbirth, 1891–2017 (11-year moving average)



The second step was to apply these age-specific marital fertility rates to all married women in Seulo and Villagrande for each year from 1891 to 2017. Consequently, we were able to estimate the number of children who would have been born if all of the married women in the two villages had conformed to the age-specific fertility rates characteristic of the natural fertility regime observed for mothers born up to 1890. The expected annual number of births was compared with the 9,811 births that occurred from 1891 to 2018, which allowed us to reconstruct the secular trend in marital fertility in the studied population (Figure 1). Children who were born as illegitimate (67) or were born to unmarried parents (82) were excluded from the observed number of births, as they had also been excluded from the computation of the corresponding expected numbers.

The trend shows that married women followed a natural fertility regime until the end of the First World War. A gradual decrease in fertility of about 20% subsequently occurred between the two world wars. A sharper fertility downturn began in the middle of the 1950s, and then accelerated and became more pronounced at the end of the 1960s. The overall fertility level fell even faster due to a strong increase in the proportion of women who did not marry (and stayed childless) during their fertile period. The share of never-married woman reached 15.4% during the natural fertility regime for the cohorts born between 1840 and 1890. It then rose sharply to 27.7% among women born in 1891–1929, and to 35.2% among those

Figure 2:
Share of stillborn, infant and child deaths in the total number of children by year of birth of the child, 1891–2017 (11-year moving average)

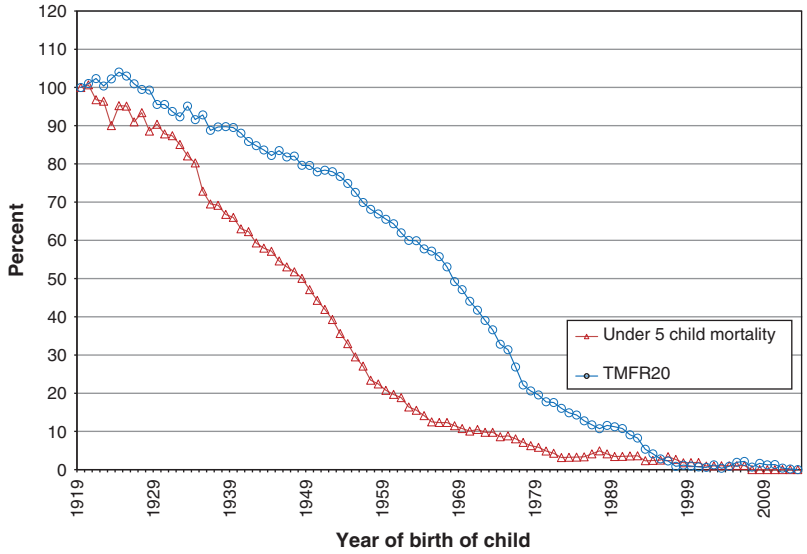


born in 1930–1959. Consequently, fertility dropped below the replacement level in the 1970s.

4.2 Trends in infant and child mortality

As early as in 1908, Coletti reported that in the 19th century, infant mortality was lower in Sardinia than it was other regions of Italy. Until 1890, it was difficult to estimate the "normal" level of child mortality under the age of five due to considerable fluctuations, and, presumably, due to the incomplete coverage of perinatal deaths. Although the two villages under study had particularly low levels of infant and child mortality, our careful investigation did not reveal any signs of significant under-reporting as of the last decade of the 19th century. Prior to the First World War, all types of mortality were decreasing at young ages; however, this trend was interrupted by the war (Figure 2). The post-war recovery was slow, and the low levels of child mortality recorded before the war were not reported again until the 1930s. In Villagrande and Seulo, the average level of infant mortality for the years 1901–1935 was 9.2%, compared with 13.6% for the same cohorts in the neighbouring village of Urzulei, and 15.2% for the years 1910–1920 in Alghero (Breschi et al. 2007). The corresponding levels of child

Figure 3:
Relative decrease in the TMFR20 and in the proportion of deaths of children under age five between 100% corresponding to the average of the years 1913–2013, and 0% for 2007–2017, by year of birth of the child (11-year moving average)



mortality were 10.6%, 14.2%, and 17.5%, respectively. After the Second World War, mortality at young ages decreased sharply in the two villages, as it did in all of Sardinia (Gatti 2002).

4.3 Aggregate association between the decline in marital fertility and the decrease in infant and child mortality

The aggregated figures indicate that the declines in infant and child mortality and the level of marital fertility were synchronous. However, in the comparison of the two relative decreases, the decline in mortality appears concave, whereas the decline in fertility follows a more convex curve (Figure 3).

4.4 Individual approach to the association between the decline in marital fertility and the decrease in infant and child mortality

What type of association between the fertility of the mother and the survival of her children occurs at the individual level? Could this association, if it exists, be

responsible for the apparent synchronisation between the decline in fertility and the decrease in infant and child mortality at the aggregate level?

To answer these questions, we first explore the association between the survival of the child and the probability of giving birth to another child. The probability of having another child after the loss of the previous one due to stillbirth or death in infancy is generally higher than when the new-born survives its first year. In order to investigate this association more deeply, we compared mothers born before 1891, between 1891 and 1930 and after 1930, who represented the pre-transitional, transitional and post-transitional cohorts, respectively. Additionally, we identified the mother's age at the delivery of the previous child (before or after age 35); and, for the mothers in the transitional cohort, whether the year of birth of the previous child was before or after 1950, a year considered pivotal to the fertility transition. In the completed families under the natural fertility regime, the probability of giving birth to another child after a previous child had died in infancy (before age one) was about the same as it was when the previous child was still alive at that age (Table 2). We found a similar situation for the mothers born between 1891 and 1930, except if the mother was younger than 35 years old, or if her previous child had been born after 1950. For these mothers, as well as for those born after 1930, the probability of having another child was significantly higher if the previous child had died. These findings indicate that couples tended to replace their lost child; among the post-transitional cohorts, this pattern was found to hold regardless of age.

For mothers who gave birth to another child, we investigated the association between the interval before the next birth and the survival of the previous child (Table 3). As expected, we found that regardless of the mother's age group, the birth interval was considerably reduced if the previous birth was a stillbirth or an infant who died before reaching age one. Given a positive association, at a constant level of fertility, the number of births per woman should be larger when infant mortality is higher.

The probability of giving birth to another child and the length of the birth interval both suggest that the proportion of stillbirths and the level of infant mortality were associated with maternal fertility. By contrast, the share of stillbirths and childhood deaths within families was more important when the size of the family was larger (Figure 4). Taken together, these findings suggest that the association between a mother's fertility and the early mortality of her children was bi-directional.

The correlations between the proportion of stillbirths, children who died before age one and those who died between ages one and five on the one side, and the number of children born to the mother and the mean birth interval on the other side, are shown in Table 4. A distinction is made between mothers born between 1840 and 1890 and between 1891 and 1930. For the cohorts of mothers born after 1930, these correlations are not significant due to the small number of stillbirths and child deaths. Except for the proportion of stillbirths, the correlations are positive with the number of children and negative with the average birth interval, and all are statistically significant with a p-value < 0.01.

Table 2:
Probability of giving birth to another child when the previous child had died or was still alive at age one by cohort and age group of the mother

Birth cohort of mother	Age of mother at birth of previous child	Year of birth of previous child	Number of mothers	Probability of having another child: if previous child alive at age one (%)	Probability of having another child: if after the previous child died before reaching age one (%)
Prior to 1891	Less than 35 years	All	82	96.1	96.3
Prior to 1891	35 years and older	All	501	62.8	63.2
1891–1930	Less than 35 years	Before 1950	80	95.5	96.3
1891–1930	35 years and older	Before 1950	66	89.1	91.4
1891–1930	Less than 35 years	1950 and later	245	66.3	74.4
1891–1930	35 years and older	1950 and later	321	52.2	52.3
After 1930	Less than 35 years	All	636	72.2	91.9
After 1930	35 years and older	All	422	29.9	63.6
All mothers	**All**	**All**	**2353**	76.5	84.3

Finally, we investigated the number of children who were alive at age five resulting from the combined effect of the mother's fertility and the mortality of her children. Figure 5 displays the average number of children who survived to age five by the year of birth of the mother's last child. This indicator, which combines the fertility of the mothers and the mortality of their children, fluctuates above the threshold of four children until the 1970s, and does not decrease sharply until after this point.

5 Discussion

Family reconstruction data has been used extensively to study the fertility transition and its relationship with child mortality. However, this research has not yet provided

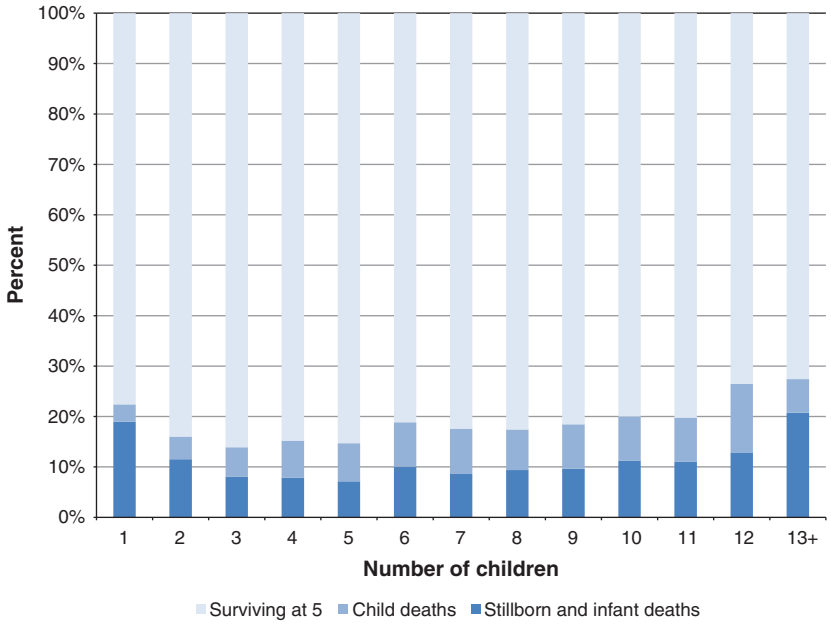
Table 3:
Mean birth interval when the previous child had died or was still alive at age one (including stillbirths, including or excluding last birth interval) by cohort and age group of the mother

			Mean birth interval in months			
			Excluding last interval		Including last interval	
Birth cohort of mother	**Age of mother at birth of previous child**	**Year of birth of previous child**	**Previous child alive**	**Previous child died**	**Previous child alive**	**Previous child died**
Prior to 1891	Less than 35 years	All	31.1	19.4	32.0	20.5
Prior to 1891	35 years and older	All	32.6	23.9	36.8	26.4
1891–1930	Less than 35 years	Before 1950	30.6	19.8	32.1	20.6
1891–1930	35 years and older	Before 1950	29.5	20.1	34.6	22.6
1891–1930	Less than 35 years	1950 and later	31.3	21.9	36.2	26.7
1891–1930	35 years and older	1950 and later	27.2	20.9	32.2	23.9
After 1930	Less than 35 years	All	29.8	20.7	41.1	21.0
After 1930	35 years and older	All	23.0	18.9	34.8	19.9
All	**All**	**All**	**30.6**	**20.2**	**35.1**	**22.2**

us with a clear understanding of the ways in which changes in mortality at young ages affected the reproductive decisions of couples during the fertility transition. In order to make progress in this field, the results of studies based on aggregated data should be complemented by findings based on individual behaviour obtained from genealogical data (Sánchez-Barricarte 2018). Does the decrease in infant and child mortality precede the decline in marital fertility, or vice versa? The association between these two processes still seems to be unclear, and should be studied in more detail with new data in order to identify possible underlying causal relationships.

The originality of our contribution stems from the in-depth view it provides of the association between the declines in fertility and mortality from both an individual and an aggregate perspective. In Villagrande and Seulo, as elsewhere in Sardinia, these fertility and mortality transitions occurred later than they did in the rest of

Figure 4:
Proportion of children living or deceased before reaching age five by the total number of children per mother with a complete fertility history during the natural fertility period (mothers born between 1840 and 1919)



Italy (Livi-Bacci 1977; Breschi 2012; Salvati et al. 2019). General fertility dropped below the replacement level in the 1970s as the result of a decrease in marital fertility and a rise in the proportion of women who did not marry up to the end of their reproductive span. Our findings show that a synchronous relationship existed between the decrease in childhood mortality and the decline in marital fertility. These trends originated between the two world wars, and then accelerated from the 1950s onwards. On the basis of this synchronism, we hypothesise that there may have been causal relationships between the decrease in childhood mortality and the decline in marital fertility.

However, despite their synchronism, these trends also exhibited differences. The decrease in mortality had a concave shape, whereas the decline in marital fertility was more convex. Based on aggregated data, we could interpret this finding as an indication that the decrease in childhood mortality was at least partly responsible for the simultaneous, albeit somewhat slower decline in marital fertility. However, the difference between the two trends could simply be due to the speed of changes induced by underlying factors. It is possible that in this traditional society, mortality responded relatively quickly to medical innovations and sanitary improvements,

Table 4:
Correlations between the proportion of stillbirths, children deceased before age one and between ages one and five per mother, the mother's number of children and the average birth interval

	Mothers born prior to 1890	Mothers born 1891–1930	Mothers born prior to 1890	Mothers born 1891–1930
	Number of children		Average birth interval	
Number of mothers	*583*	*712*	*583*	*712*
Proportion of stillbirths	0.158**	0.037	−0.044	−0.059
Proportion of infant deaths	0.114**	0.201**	−0.188**	−0.0118**
Proportion of child deaths	0.165**	0.198**	−0.182**	−0.098**
Proportion who died before age five including stillbirths	0.231**	0.255**	−0.312**	−0.016**

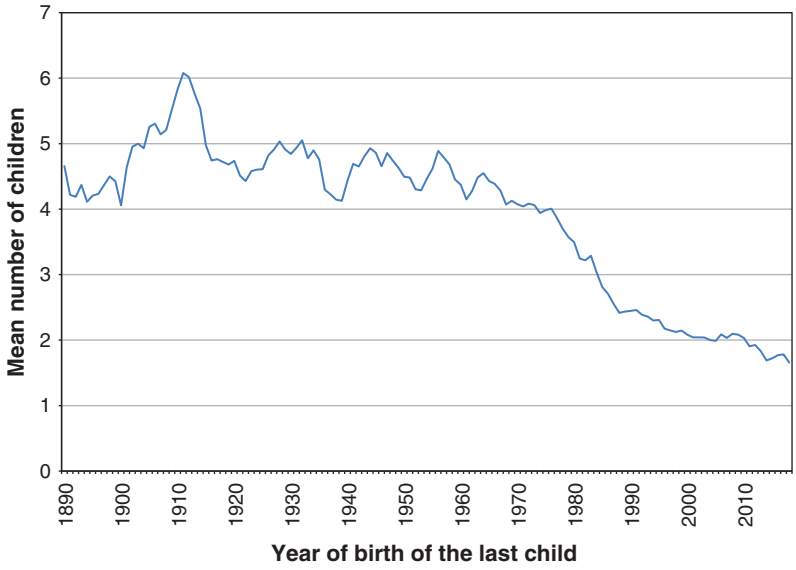
Note: **Statistically significant with $p < 0.01$.

while marital fertility was less responsive to underlying socio-economic and cultural changes. In Villagrande and Seulo, as elsewhere in Italy, these developments might have been influenced by the pro-natalist policy promoted by Mussolini in the 1930s.

A closer investigation of the mothers' individual fertility histories gave us a better opportunity to discern possible associations between the two processes. First, we examined the association between a child's survival and the probability of having another child. According to the replacement theory formulated by Schultz (1969), the decision to give birth to another child is deliberate. In the case of the two villages studied, this assumption appears to be confirmed by the fact that the name of a deceased child was often given to one of the following children of the same sex. However, we did not observe such conscious behaviour during the natural fertility regime; it first emerged during the transitional period, and did not become widespread until the post-transitional stage.

Empirically, the decrease in the number of stillbirths and infant deaths had a direct effect on fertility, as the birth intervals become much shorter after the loss of a child. Nevertheless, this effect was somewhat limited among our studied populations. Our finding that the average birth interval was 22 months after the death of a child, rather than 35 months if the child remained alive, implies that fertility might be no more than 15% lower, considering the average level of infant mortality. This factor, as

Figure 5:
Mean number of children alive at age five per mother with a complete fertility history by year of birth of the last child (five-year moving average)



opposed to the desire to replace a lost child, cannot be considered deliberate, but could be explained by physiological reasons, and its direct impact was slight.

Both of the factors we investigated suggest that the level of infant mortality, including the proportion of stillbirths, was positively associated with relatively higher fertility. Considering this association, the decline in stillbirths and infant mortality among our studied populations might have been at least partly responsible for the corresponding decrease in fertility.

From a different perspective, we observed that mothers with complete fertility histories who had more children or shorter birth intervals tended to have higher proportions of stillbirths and infant mortality. Our findings indicate that the number of children born to a given mother, as well as the corresponding mean length of her birth intervals (excluding those following an infant death), had an influence on the children's survival. A child had a better chance of surviving if the length of the birth interval since the previous birth was longer and the number of surviving siblings was smaller when he or she was born. Accordingly, a mother with lower fertility might have had a lower risk of losing her children. In this case, a decrease in fertility could have also resulted in a decrease in infant mortality. While the correlation we found between a mother's completed fertility and the survival of her children confirmed that there was an association between them, it does not shed light on the nature of this causal relationship.

In Villagrande and Seulo, the average number of children alive at age five tended to stay stable, at close to five per mother during the entire observation period until the 1970s, when analysed by the year of birth of the last child. Did the mothers reduce their fertility in order to keep the same number of children alive up to age five, given that infant and child mortality was decreasing? Our findings support the suggestion of Reher et al. (2017) that the number of surviving children, rather than a specific number of births, serves as an important predictor of the likelihood of having another child. During the transitional and post-transitional periods, this could indicate a conscious decision on the part of couples to limit the total number of children expected to survive. In order to maintain such stability after child survival improved, couples had to reduce their fertility. Nevertheless, even if all children survived until the age of five, the maximum expected impact on fertility would not have exceeded a 20% decrease.

It is also possible that losing a child had both physiological and psychological effects that reduced a couple's fertility (Knodel 1988). The psychological effects may operate at both the individual and the community level. Nevertheless, the effects at the community level should only emerge after a significant decline in infant and child mortality. Could a sudden and significant reduction in infant and child mortality, like the one we observed at the beginning of the 1950s, have unconsciously influenced couples to have no more children? The question remains unanswered.

In addition to the effects discussed above, the association between fertility and child survival cannot be explained without considering the socio-economic and cultural context. Socio-economic and cultural factors, such as an increase in well-being, more conscientious infant care, and better health at the community level, could be responsible for simultaneous decreases in fertility and child mortality. Recent research has repeatedly shown that in addition to the decrease in childhood mortality, the increases in levels of education and economic development played important roles in the historical decline in fertility (Sánchez-Barricarte 2017, 2018). While the economic context clearly contributed to the decline in child mortality, economic growth was also consistent with the fertility decline (Brown and Guinnane 2018). Cultural and social factors conditioned the reproductive behaviour of couples, but mortality may have also been affected by (temporal) socio-economic and political conditions. Livi (1961) and, more recently, Salvati et al. (2019) identified a period between the two world wars as a particularly relevant turning point in demographic dynamics. A similar period was noted during the 1970s. Both studies identified indicators characterising the pre-transitional, transitional and post-transitional phases of development.

In the case of the two villages in Sardinia, important changes occurred after the Second World War that significantly improved the well-being of the local population. The anti-malaria campaign initiated by the Americans in 1948 with the support of the Rockefeller Foundation had a direct impact on the sanitary conditions and health status of the local population (Tognotti 2009). At the same time, the external world became more accessible to the two villages due to better communications; the exchange of goods, services and ideas; and more exogamous marriages. According

to our anthropological surveys of couples born in the 1920s who were affected by these changes, several policies introduced in the 1950s stimulated improvements in the welfare of these traditionally rural populations, including changes in social security, pensions and access to health services. The introduction in 1962 of the compulsory education of children up to age 14 altered the role of children in their families. Boys became less available to help in the fields and to tend the animals, whereas girls provided less help with the housework. Increased emigration, higher levels of education, especially for girls, and better knowledge of contraceptive methods resulted in a sharp decrease in the number of children. From that period onwards, most couples limited their number of children to two or three. This shift occurred even before 1984, when the use of contraceptive pills became more common in both villages.

Our decision to focus on the two small villages was linked to our earlier research on the extreme longevity of their populations, which also revealed that these villages underwent the first demographic transition very late. While the fertility transition started between the two world wars, infant mortality did not decline sharply in these villages until after the Second World War. The small size of the population included in the analysis could be considered a limitation. However, the data are unusually complete, which enabled us to demonstrate the synchronism between the declines in fertility and mortality. Moreover, our long-term focus spanning from the late 19th century until the present was important, as the changes under study started later than they did in other regions of Italy. The conscious and unconscious actions taken by couples indicate that the decrease in mortality contributed to the decline in fertility. Nevertheless, the main impetus for the decline in fertility and the decrease in mortality was provided by the favourable socio-economic conditions that emerged in the 1950s, when the studied population gained greater access to the modern world. Many villages in other parts of Italy have been studied using comparable datasets for the same period. Accordingly, further comparative studies involving a variety of communities that differ in their economic, social and cultural characteristics are needed. Such studies could shed light on the specific economic and cultural factors that affect the fertility and mortality transitions, and their synchronism.

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