The Intergenerational Transfer of Infant Mortality in Northern Norway during the 19th and Early 20th Centuries

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HISTORICAL LIFE COURSE STUDIES

Intergenerational transmissions of infant mortality using the Intermediate Data Structure (IDS)

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The Intergenerational Transfer of Infant Mortality in Northern Norway during the 19th and Early 20th Centuries

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ABSTRACT

This paper is one of a series of five studying the intergenerational transfer of infant mortality down the maternal line. All five studies share the same theoretical and methodological design, and use data derived from a standard database format: the Intermediate Data Structure (IDS). The data for the research reported in this paper were derived from a longitudinal dataset covering the 19th and 20th century population of the province of Troms in Northern Norway. Our results suggest that there *was* an element of intergenerational transmission in women's risk of experiencing an infant death; the children of a woman whose mother had had a high number of infant deaths also had a greater risk of dying before their first birthday. The risk of an infant death occurring among the children of daughters from such 'high risk' families was at least 30 per cent higher than that amongst infants born to the daughters of mothers who had experienced zero infant deaths.

Keywords: Infant mortality, Intergenerational transmission, Norway, 19th Century, Intermediate Data Structure

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1 INTRODUCTION

This paper reports on research into the intergenerational transfer of infant mortality undertaken on a longitudinal dataset covering the province of Troms in Northern Norway for the period 1840 to 1924. It investigates the extent to which the level of infant mortality amongst the children of mothers in a 'first generation' correlated with the infant mortality level amongst the children of their 'second generation' daughters. We hypothesize that there was intergenerational transmission of mortality risk down the maternal line, such that daughters would have faced an increased risk of death amongst their own infants if their mothers had also experienced infant deaths.

The clustering of infant deaths within particular families has been studied for some time (e.g. Das Gupta,1990; Edvinsson, Brändström, Rogers, & Broström, 2005). Remarkable similarities in this phenomenon have been found across a range of localities, with more than half of observed families in each population never experiencing a single infant death, while others lost a high proportion of their children. The evidence for such clustering of mortality within families has convinced scholars to turn their attention away from an individual level to family level factors when investigating the causes of infant mortality (Edvinsson et. al, 2005).

Using an intergenerational perspective, Vandezande (2012) has demonstrated that high infant mortality among siblings in one generation resulted in a significantly higher risk of infant death in the next generation, irrespective of whether the maternal or the paternal line was followed. We also know that biological effects may serve to increase the risk of infant mortality across generations (Vandezande, 2012). The risk of a miscarriage or a difficult delivery may be genetically determined, for example, and weak or so-called 'faulty' genes may increase the risk that an infant will die soon after birth. The exact role of biological effects is difficult to determine, particularly when analyzing intergenerational outcomes as there are considerable selection effects involved. This can be explained given that infants who die cannot reproduce themselves. It is also possible that explanations for similarities across generations arise from socio-cultural preferences such as family size, age at first birth and childcare behavior, such as whether or not children are fed artificially (Brändström, 1984). These types of norms are generally passed down from mothers to their daughters and are often shared widely across members of a particular community, but they can also vary from individual to individual within the same social or denominational group, making it very difficult to measure their impact on infant mortality (Walhout, 2010).

Environmental factors may also have affected the transfer of the risk of infant mortality across generations if the families resided in the same area for multiple generations. Contaminated water from local wells could potentially cause a higher incidence of diseases such as diarrhea, for example. Although polluted water was frequently referred to as a health problem in the yearly medical reports written by district doctors in Norway, diarrhea continued to be registered as a cause of death among infants (Balsvik, 1989; Jåstad, 2006), suggesting that conditions did not improve over time.

The resources available to a family, which are often proxied by the father's occupation, may also have acted as a determinant of intergenerational clustering of infant mortality, particularly in societies where social mobility was low. Also, in relation to available resources, an infant's survival chances have been found to be related to his or her position within the sibling group. The more siblings a child's mother had had, the higher the child's risk of dying. This may have been related to maternal depletion which sees a woman's health deteriorating as the number of her deliveries increases. This in turn may result in lower birth weight babies which then are at higher risk of infant death. In addition, the more living children there were in a family, the higher the competition for the available physical and emotional resources. This has been found to have a more or less linear relationship to the risk of infant death (Knodel & Hermalin, 1984).

A woman's health during pregnancy, delivery, and her baby's critical first few days are crucial to the infant's survival. Fure (2002) has demonstrated that this relationship may have its roots even earlier in the mother's life. In an analysis of infant mortality in one Norwegian parish, she found that women born in years with high infant mortality had an increased risk of giving birth to infants who died in the neonatal period. This suggests that a woman had been born under adverse conditions, such as encountering either disease or undernourishment *in utero* or in early infancy. More women in such cohorts may have been 'programmed' to bear a greater number of weaker, low birth weight infants than women who were born in years when infant mortality was low. Interestingly, Quaranta (2013) has observed that early life exposure to adversity had an intergenerational effect on mortality in a study covering the southernmost province of Sweden, and an interdisciplinary research team found that large fluctuations in food availability during the early development of the grandparental generation from Överkalix, Sweden, resulted in an excess risk of cardiovascular mortality

among their adult female grandchildren born in the late 19th and early 20th century, although this effect was only statistically significant between grandchildren and their parental grandmothers (Bygren et al., 2014). Such studies reflect the growing interest in epigenetic research in recent years. This field aims to explain how environmental conditions affect the human gene system, and to deduce how this might, in turn, affect life expectancy across generations.

The research on which this paper is based was both methodological and educational in scope. It is one of a series of five studies sharing the same theoretical and methodological design, which will all be published in this journal. In addition to the Norwegian data presented in this paper, the other studies use data from Sweden (the POPUM and the Scanian Economic Demographic Database (SEDD)), Belgium (COR*) and the Netherlands (LINKS Zeeland). In each case, the research teams converted their own unique longitudinal datasets into the same standard data format: the Intermediate Data Structure (IDS) (Alter & Mandemakers, 2014). Shared computer code, written in STATA, was then used to prepare each dataset for analysis and to run the basic statistical models (Quaranta, 2018b).

2 THE PROVINCE OF TROMS

The data for the research described here were drawn from the censuses and church books of Troms province, which lies in northern Norway, for the period 1845 to 1924. Troms is located north of the polar circle and is the second northernmost province in Norway and covers an area of 26,203 km^2. Norwegian provinces are usually divided into a number of municipalities, units of civil administration consisting of one or more parishes. Troms province comprised sixteen municipalities in 1865 but had been further divided into 27 municipalities by 1910. Between 1845 and 1922, Troms experienced a population growth from about 45,000 to 75,000 inhabitants, an increase of some 67 per cent; more than twice the rate of growth Norway's population in the same period.

The deep fiords dividing the province form waterways which provide year-round access to various fishing grounds, with agricultural land along their shores. The most common form of household economy for families living on the sea coast or along the fiords was a combination of fishing and farming arranged on a subsistence system (Bratrein, 1992). Labour was strictly divided along gender lines; by participating in seasonal fishing in remote fishing grounds the men secured access to market goods and cash income, while women took care of domestic duties and work in the farmyard (Balsvik, 1989). A cow, some sheep, and occasionally a goat or a pig provided milk and meat. Although most households undertook both fishing and farming, it was not unusual for families along the coast to be more or less dependent on fishing, while families in the inland areas of southern Troms, which had little access to the sea, occupied relatively large farms and were mainly dependant on agriculture for their subsistence and income.

As the middle province within Northern Norway, Troms is geographically situated between two major seasonal fishing grounds; the Lofoten grounds to the south, and the Finnmark grounds to the north. It is also close to a third large fishing ground, situated in the Breivikfjord, in the southern part of Finnmark, and known as the "Little Lofoten" grounds. During January, when the sun never rises, and February, fishermen gathered for the fishing season on the Lofoten fishing grounds. Later, during spring and early summer, they shifted their activity to cod fishing on the Finnmark grounds.

During the second part of the 19th century a more modern sector of the economy developed, and there was greater employment to be had in mining, crafts and commerce. In the provincial capital of Tromsø, commerce and trade developed swiftly. In Alta, just to the north of Troms, a copper mine was established in 1827, and another was soon opened in Kvænangen, an inner fiord community within Troms; this was in operation from 1840 to 1875. Mines and metal working provided an income in the weather-beaten coastal regions of Troms, where the seasons changed abruptly, fishing fleets could be storm-bound for weeks and neither fishing nor farming could be relied upon to provide a living, the nickel plant on the island of Senja gave employment to up to 500 workers from 1872 to 1886. The development of industry and commerce gave rise to a large influx of migrants, which, as mentioned above, powered rapid population growth in the province. The opening of the mines and nickel plants, and their closure, meant, however, that the various areas within Troms could experience quite different levels of in- and out-migration (Thorvaldsen,1995).

Family life in this Arctic region, when one's livelihood depended solely on the annual harvest from the sea and/or the land, was unpredictable from year to year. In some years spring arrived early, followed by a short, intense summer yielding enough grass to feed a cow for the winter, but the men would return from the fishing grounds with empty wallets. In other years, spring and summer temperatures would not creep above +10 degrees Celsius, and although fishing would bring in some income, a large part of this would have to be spent paying off the previous year's credit owed to the local merchant. One thing that was predictable was the arrival of a new born child every second year. Babies were delivered at home and, if assistance was needed, it was usually provided by an untrained midwife or "hjelpekone". Troms' 26,200 square kilometres were divided into 5 medical districts in the mid-19th century, served by 9 doctors and 10 trained midwives. Fifty years later, in 1902, the number of doctors had more than doubled, to 24, and that of midwives had almost quadrupled to 38. By this date the original medical districts had been split up, so that there were now 11 of them. Nevertheless, a doctor could still be responsible for some 6,000 people spread over an area of 6,000 km^2; this was certainly the case in Skjervøy parish. Despite improvements in communication with the setting up of a regular steamboat route and the expansion of the telegraph system, in their yearly medical reports the doctors often describe the frustration of arriving too late to be able to save a patient's life, or to put measures in place to stop the spread of an epidemic. The doctors who, either for adventure or through duty, came north for a limited period, would have encountered a region with a climate and a culture quite different from the places they had been born, raised or educated. Some of these men noted their observations of the inhabitants and their living conditions in words that exude haughty distain, while others tried to give an objective statement of what they saw while conveying a political ambition for change, addressed to the health authorities who sat in government 1,200 km south. The tone of these reports is encapsulated in their descriptions of straitened circumstances, cramped quarters with bad ventilation and insanitary conditions, the leaching of manure into the wells, malnutrition, and people's apparent inability to plan for bad years to come, but spending the small income they had on coffee, sugar and liquor instead. However, when reading the reports written by doctors who settled in the region for longer periods of time, we find that they took a somewhat broader perspective, with narratives which mention development and improvements, such as better housing, including water pipes, and an increased awareness of official health regulations.

A brief look at Norway's overall mortality levels between 1846 and 1920, as presented by Official Statistics of Norway (NOS), reveals two striking features: the first is the exceptionally low level of mortality for the period with 17-18 deaths per 1000 population and, the second is the relative stagnation of the mortality rate between the mid-19th century and the late 1890s. After the latter date, a continuous decline set in, interrupted only by the Spanish flu epidemic of 1918-19. Compared to infant mortality rates in other countries at the time, the infant mortality rate in 19th century Norway was low; in 1840, 140 of the country's infants died per thousand live births, a figure which began to ebb slowly in the 1870s, before dropping quickly from the late 1890s onwards (Backer, 1961).

The demography of Northern Norway in our study period was somewhat different from that of the country as a whole, being characterised by a low age at marriage and high fertility, combined with a general decrease in mortality, primarily driven by a decline in child mortality. In addition, as we have seen, population growth in the region was also augmented by in-migration. While this is a typical picture from the second stage of the demographic transition, studies from Northern Norway suggest that this Artic region experienced higher average mortality levels and higher fertility levels than the other provinces in Norway (Sogner, Fure, & Randsborg, 1984).

3 DATA SOURCES AND DESCRIPTIVE STATISTICS

The Norwegian Historical Population Register (HPR) project aims to produce a national population register for the period from 1800 until 1964, when Norway's modern population register was established. The HPR is being constructed by merging and linking the information given in the nominative censuses of 1801, 1865, and every 10 years thereafter, to the details contained in the church books recording baptisms, marriages, and burials. When finished, the HPR will cover the whole of Norway, thus allowing internal migration to be observed, albeit indirectly. This will then allow the periods which individuals can be observed in particular social or geographic contexts to be measured more accurately. It should be noted, however, that the data used in the research reported here do not contain migration events.

Before we introduce the sub-sample of data retrieved from the HPR for use in the collaborative project, let us take a brief look at the primary building from which it is being constructed, namely the church registration books and population censuses. During the period covered by the HPR, the primary sources changed, both in form and in content. Norway's central authorities demanded priests to report the numbers of those born, deceased and married in their parish from as early as 1735 (Royal decree of Dec. 30th 1735). Some priests felt that such reporting went beyond their clerical concern for their parishioners, and it is therefore perhaps not surprising that there appears to have been consistent underreporting in the 'official statistics' compared to the number of events registered in the church books (Herstad, 1975), suggesting that the latter are the more reliable source. That said, the quality of ecclesiastical registration during the late 17th and early 18th centuries, varied greatly. Burials, and infant burials in particular, tended to be under-registered; some studies suggest by as much as 20 per cent (Høgset, 1990). In the earliest years of registration, the church books typically had no defined headings, columns or divisions between the different types of event. Printed forms emerged gradually from 1812 onwards, and the new books had pre-defined sections for baptisms, burials and marriages. The registers were redesigned in 1877, so as to meet not only the Church's need to monitor the population under its care but also to collect the information sought by the statisticians working at the newly established Statistics Norway.

A baptism record in the 1840s typically included, in addition to the dates of both baptism and birth, the name and sex of the baptized child, the names of his or her parents; whether or not the birth was legitimate, the parents' place of residence, and the names of any godparents. The father's occupation was recorded from the 1850s, and when the forms were redesigned in 1877, the parents' years of birth were added in a separate column. As early as the 1820s priests were asked to register the cause of death of the deceased when recording a burial, at least in cases where the death was the result of an accident or a contagious disease. From 1877 the cause of death information to be collected was widened to cover all causes. Before 1877 the death records gave the dates of burial and death, plus the name, occupation, place of residence, and age of the deceased. After 1877 if the deceased was a married woman her husband's name and occupation were to be recorded and if the deceased was a child then the father's name and occupation was to be given. The importance given to the paternal line of decent is also seen in the registration of marriages; from 1820, in addition to standard information about the newlyweds, such as date of marriage, name, age, occupation, place of residence and place birth, the names of the fathers of both bride and groom were to be given, and from 1877 the fathers' occupations were also recorded.

Census forms also changed over time. The 1801 census collected information about a given person's name, position within the family and household, marital status, occupation and age. By 1910 the census questionnaires had expanded to include additional information on place of birth, citizenship, religion, infirmities, ethnicity, and language spoken. Of course, the changes mirror the issues which the Norwegian government and the official statisticians viewed as being of administrative or statistical interest at any particular time.

It is noticeable that, even without the changing design of the registration forms and the different information requested, priests and parish clerks showed great variation in the way they filled in the records. Some of the entries in the church books bear witness to the priest's organization and his detailed knowledge of his parishioners, while others indicate that the priest had reluctantly scribbled down a minimum of information, possibly well after the events he was recording by which time he had forgotten the names and ages of the people involved.

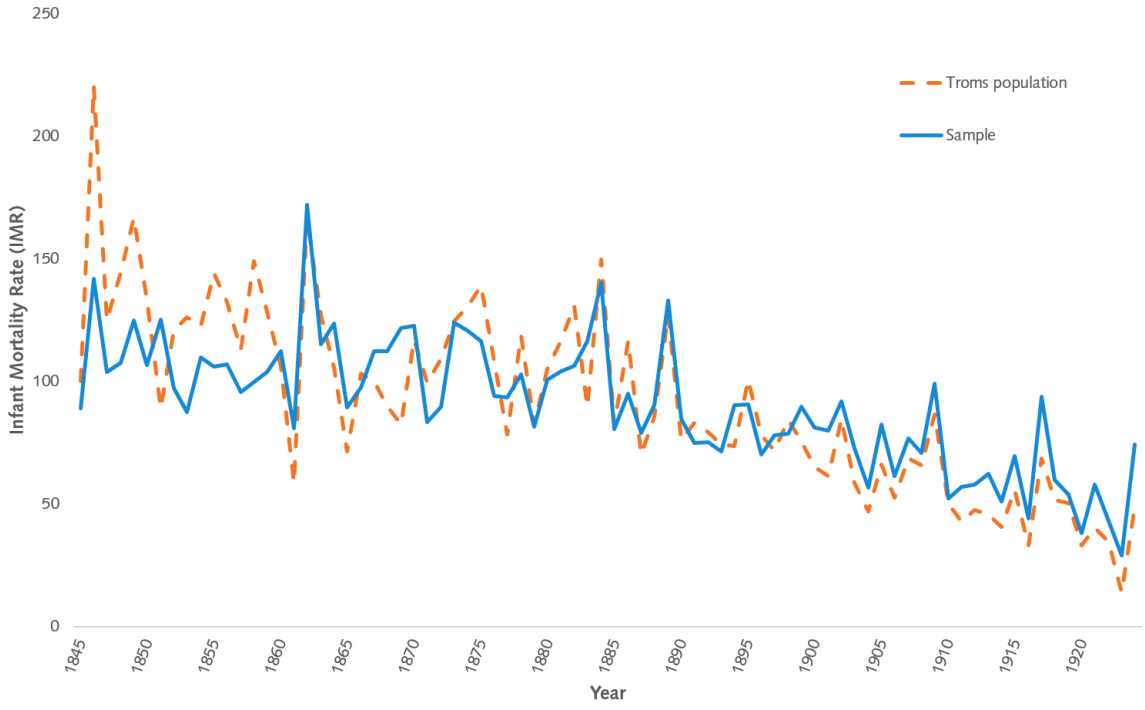
Changes in registration practice mean that different critical questions have to be asked of the sources at different points in time and these will be discussed in the following sections. First of all let us consider the linking process involved in the construction of the HPR from the original sources. Once the information provided on individuals in the census and events in the registers has been transcribed, a set of automatic record linkage routines, developed specifically for use with HPR, are used. The marriage records are taken as the starting point. Marriages are used to create links both forward and backward in time, linking the marriage to the children born and baptized after the wedding, and using the name of the fathers of the groom and the bride to link to events within their families prior to the marriage. At present links within the HPR are biased towards those in marital unions, but we are optimistic that linking rates for never married persons will also be good, once married people have been removed from the pool of potential matches.[1]

For the purposes of the current study, a sub-sample of women from the HPR database was retrieved which allowed us to follow the reproductive life courses of mothers and their surviving daughters, see

1 For a detailed overview of the linkage classification, see Thorvaldsen, Andersen, and Sommerseth (2015, pp. 155-172).

Table 1. This sample consists of a 'first generation' of mothers who had at least two births, one of which had to be a female who survived into adulthood and had children of her own. The daughters were our 'second generation' and their children were the 'third generation'. Contextual information about the husbands of women in the first and second generations was also collected.

Figure 1 *The infant mortality rate, Troms province, 1845-1924; study sample and total population*



Source: HPR dataset Troms 2017 (IDS-version).

Figure 1 shows the annual infant mortality rates in Troms from 1845 to 1924, both for the population as a whole and for our sample population. The rates amongst the latter adequately replicate the rates for the total population, although they were somewhat higher in the first two decades of the observed period and slightly lower in the last 25 years. Up until the year 1890, the infant mortality rate varied from one year to the next; in some years it was as 'low' as 50 deaths per 1000 births while in other years between 15 and 20 percent of infants died. Such violent fluctuations became rarer after 1895, and even when peaks years did arrive, mortality never rose above 100 deaths per 1000 births. If the figures for Troms are compared to the national figures published by Official Statistics of Norway (NOS), it would appear the province experienced quite similar mortality patterns to the country as a whole, although the figures were probably more in line with the national average figures for urban, rather than rural, areas (Backer, 1966; Sogner, Bull, & Gjelseth, 2002, p. 78).

Table 1 shows that the population sample extracted from the HPR using IDS includes 3,517 first generation mothers, born between 1783 and 1886. These women gave birth to 23,641 children, out of which we were able to follow 5,498 daughters (23.3 per cent of the total), each of whom survived into adulthood to give birth themselves and went on to live out their reproductive life in Troms. Both the first and second-generation mothers had, as expected, quite high fertility, although fertility was, on average, lower amongst the second generation than amongst the first. This observed difference in fertility between the generations does not necessarily reflect a change in fertility behavior but could merely be a consequence of our selection process as first-generation mothers had to have had a minimum two births, one of which had to be a daughter who survived to adulthood. Within both generations a strong interplay between mortality and fertility behavior can be observed; women who bore higher numbers of children also experienced a higher number of infant deaths, on average. This interaction has been found elsewhere, particularly in fertility studies exploring spacing and stopping behaviors (Van Bavel, 2004), but also in studies of infant mortality (Lynch & Greenhouse, 1994). A number of different explanations for this relationship have been put forward. One, emphasizing biological mechanisms, suggests that where the preventive effects of breastfeeding were interrupted

by the death of a nursing child, a new pregnancy often followed. A second explanation is that shorter birth intervals after the loss of a child may reflect a deliberated decision to 'quickly' replace the deceased child (Knodel, 1982). A further, related effect of shorter birth intervals has been found in contemporary studies which have shown that women who have short intervals of less than 18 months between pregnancies are at increased risk of having a preterm birth (DeFranco, Ehrlich, & Muglia, 2014), which, of course, increases the risk of death in early infancy.

Table 1 *The number of women and the mean number of births per woman, in the first and second generations, by the number of infant deaths experienced by the first generation women and the second generation women, independently, Troms province, 1845-1924*

	Mothers				Daughter(s)		
Infant deaths	**Total**	**%**	**Mean births**		**Total**	**%**	**Mean births**
0	2,027	57.6	5.9		4,018	73.1	4.1
1	971	27.6	7.2		1,069	19.4	5.8
2	340	9.7	8.3		287	5.2	7.7
3	126	3.6	9.7		95	1.7	8.6
4	36	1.0	11.2		21	0.4	9.7
5	12	0.3	12.9		7	0.1	11.9
6	4	0.1	12.3				
7	1	0.03	14.0				
	3,517	100.0	6.7		5,498	100.0	4.8

Source: HPR dataset Troms 2017 (IDS-version).

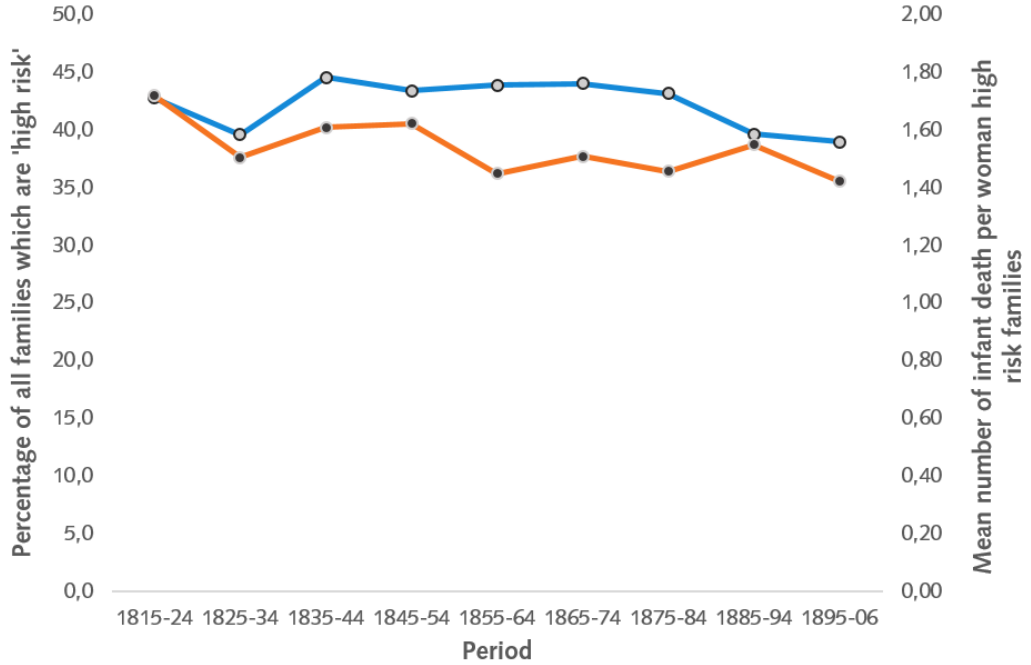
Given that the mean age at marriage amongst the first-generation mothers in our sample was 28.5 years, this would mean that each woman had, on average, 20 years to complete her family, so those women achieving the highest numbers of children could only have done so if some of the intervals between their births were shortened because of the death of the child opening the interval. This gives rise to a strong correlation between high fertility and high mortality, which is more prevalent amongst the children of the first generation than among the second generation who were, on average, 3.4 years younger on their first marriage than their mothers. In the first generation 14.8 per cent of mothers lost two or more children through death in infancy, while only 7.5 per cent in the second generation did so; 5 per cent of the first-generation mothers lost 4 or more children, but this was the lot of only 0.5 per cent of the second generation.

What is even more striking in Table 1 is the proportion of families which suffered no infant deaths at all: 57.6 per cent of first generation mothers and 73.1 per cent of second generation mothers never experienced an infant death. More than half (58.7 per cent) of the second-generation mothers never experienced the loss of a child nor the loss of a sibling (not shown in Table 1).

As previously shown in Table 1, 42.4 per cent of first generation mothers and 26.9 per cent of the second generation had experienced the death of one or more of their children in infancy by the time they had completed their reproductive period. Hereafter we will define these as the 'high risk' families in each generation. We are interested in changes 'high risk' families experienced over time, both in terms of the mean number of infant deaths they had and in the proportion of all families in Troms which such families represented. Since a 'high risk' family will be in observation over a considerable period of time, in Figure 2 we classify the families according to the birth year of the first surviving daughter in the second generation (Figure 2), and in Figure 3 according to the birth year of the first child ever born in the third generation (Figure 3). Figure 2 demonstrates that among the first generation, the proportion of families which were 'high risk' did not change much over time. Figure 3 indicates that there was a similar story amongst the second generation, up until the two last decades of the 19th century; from 1885-94 onwards a consistent decline in the proportion of high risk families is evident. By 1915-24, only 8 per cent of the families in Troms were classified as 'high risk' compared to 40-45 per cent in the first 50 years of the 19th century. Figures 2 and 3 also show the mean number of infant deaths per high risk family, and how this changed over time. Both the first and second generations saw a decline

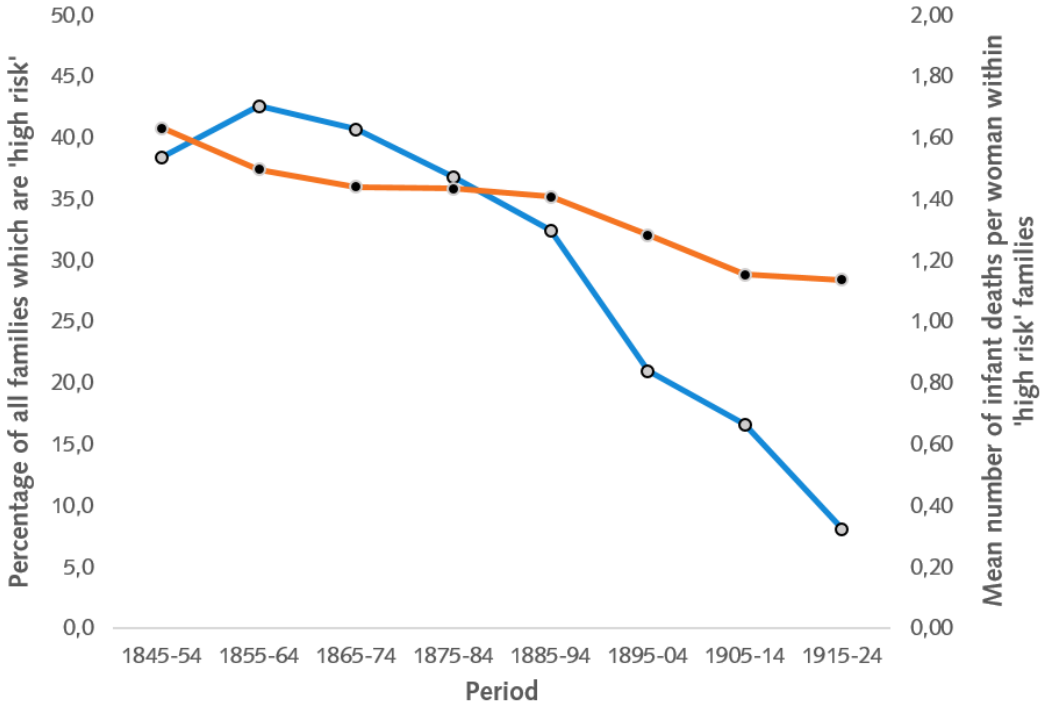
in the number of children lost, although the decline was more dramatic among the second generation, who lost 1.63 children, on average, in the mid-19th century but only 1.14 in 1915-24. The extent to which this decline caused an increase in homogeneity of experience with fewer high risk families even although infant mortality remained generally high is difficult to discern because infant mortality rates were also declining over this period (Figure 1).

Figure 2 *The proportion of all families which are 'high risk' (blue line) and the mean number of infant deaths per woman within 'high risk' families (orange line), by decade of birth of the eldest surviving daughter of first generation mothers*



Source: HPR dataset Troms 2017 (IDS-version).

Figure 3 *The proportion of all families who are 'high risk' (blue line) and mean number of infant deaths per woman within 'high risk' families (orange line), by decade of birth of the first child ever born to second generation mothers*



Source: HPR dataset Troms 2017 (IDS-version).

4 IDS AND THE NORWEGIAN HISTORICAL POPULATION REGISTER

The current paper is part of a collaborative project which is using the IDS to conduct fully comparable research across different populations for the first time. The aim of the project is to demonstrate the value of the IDS and to encourage the creation of software which can be used in common by all the research teams since the IDS carries out the standardization and dissemination of data, making the comparison of datasets easier and more accurate than if the comparative studies were conducted using independently written software with each database. The following section evaluates our experience of implementing the IDS on the Norwegian Historical Population Register (HPR), noting the advantages and possible challenges of this process.

While population registers, by definition, contain the 'life histories' of individuals, the HPR links together records of 'life events', such as birth, marriage, migration and death, to reconstruct life histories. Strictly speaking this is not family reconstitution, as developed by Louis Henry (1980). Using Henry's method, family reconstitution links the records of all births, subsequent marriages, and deaths associated with a particular marital union, in order to create a 'family history'. We apply a more flexible methodology, which allows us to include those individuals who were not involved in a marital union, and to capture additional snapshots of a person's life course. We undertake an extended family reconstitution, but then we also link individuals to the nominative information in the population censuses. To some extent, one might argue that church registers share similarities with population registers, in that the same person, the parish priest, registered different life events for individuals, as long as they remained part of community, and the registration was undertaken under a set of national regulations. Even in- and out-migration was registered, though, as stated earlier, this information has not been included in the present database. When finished, the HPR will cover the whole of Norway and therefore it will be able to identify internal migrants indirectly. On average, the 'church book' in an average sized parish lasted for 10 years. Each book was divided into sections, one for each type of event. Consequently, if a child died during its first 5 years of life, the local priest could probably find the record of his or her baptism in the same book, and thus crosscheck the child's birthdate and the names of the parents, although it should be noted that the priest was not obliged to do so. Of course, our reconstructed register, along with family reconstitutions in general, contain certain biases which are less prevalent in population registers. The most notable of these is that our linkage techniques favour those who enter a marital union, since following a man or woman who never marries is rather harder than piecing together the life histories of married couples and their families.

The IDS make a distinction between four different types of date. An *event* date refers to the actual date of an event, recorded as the event occurred. The birth date registered on a person's birth certificate is an example of an *event* date. A *reported* date refers to the date of an event which was reported in a later source. A *declared* date is a date which refers to a point in time or a period at which a particular attribute was valid. The date of a census in which an individual was recorded as 'married' is a *declared* date; showing that the individual concerned had been through a marriage ceremony at some point before the census was taken. Finally, an *assigned* date refers to a date assigned by the database administrator, on the basis of a set of stated assumptions, when the precise date of an event is not known. Where only dates of burial are known, for example, an administrator may decide that death occurred seven days prior to burial in each case. Making a distinction between the different types of dates gives the data administrators and researchers an efficient tool which they can use to determine the start date of a period in which an individual is in observation. This is usually done by selecting the earliest *event* date at which the person is recorded. In addition, differentiating between the types of date emphasizes the importance of the *time* which elapsed between an event and the registration of that event. This can be very important when carrying out a critique of one's sources, as sources which report the date of an event 2 years after the event occurred, for example, may be considered less reliable than a source in which events were registered as they happened. Let us consider dates of birth in our sub-sample from Troms, to illustrate this point. In the mid-1850s, the parish of Målselv was separated from the parish of Lenvik and became an independent parish. Before this date, the priest from Lenvik visited Målselv four times a year and held a service. The church must have been crowed on these occasions and a flurry of ceremonies were held. On Sunday July 13th 1845, for instance, 17 children were baptized, 4 marriages were blessed, and 2 ceremonies conduced in the graveyard, all of them properly registered in the church book. According to the entries the oldest child baptized was 323 days old and the youngest 33 days. This should, of course, raise questions concerning the accuracy of the dates of birth which were registered, making it uncertain exactly when the children had entered observation. Strictly speaking, the 323-day old child did not enter observation until the date

of his or her baptism *event*. One of the IDS programs designed for use by teams in the collaborative project converted a *reported* date of birth in a record of a baptism to an *event* date, indicating that the children had come into observation on the day it was born. We will never be able to determine whether the dates recorded in the registers were 100 per cent accurate. Nevertheless, we have been able to undertake some basic tests, such as checking that only dates of births which occurred prior to the date of baptism are included in our analyses. It is most important that administrators document the origins of dates in a database and make this information easily accessible to those using the data. Moreover, when the results of any analysis might be compromised by questions relating to the accuracy of dates researchers should always discuss how the latter have been derived when describing their data sources, even if the issues remain unresolved.

Undoubtedly, the accuracy of entries in the church books relating to baptisms and births were primarily determined by communication between the parents of the child being baptized and the priest recording the event. How well did the parents recall the date of their child's birth? In the mid-19th century, reading and writing skills were not widespread, and the majority of people would have had to rely on their memory. If one is analyzing overall rates of mortality in a population then the accuracy of the dates of birth and death are less important than if one is analyzing infant mortality. When carrying out the latter exercise, it is important to know whether a death occurred in early spring or around midsummer, not only when computing the mortality rates but also when discussing possible explanations for the patterns observed.

Due to the time lag between birth and baptism, we should expect some bias in the reporting of deaths, given that the deaths of children who died before they were baptized are more likely to have been under-reported. Priests did, however, register infants they had baptized at home, and those who had been baptized by another, trusted person such as the midwife. Thus, from around 1840 we find early deaths reported not only in the burial section of the church books, but also in the baptismal section, with a drawn cross next to the child's name and together with the remark 'hjemmedåp'; baptized at home. This reduces the possible bias in mortality substantially, and the descriptive statistics of our sample population show the expected distribution of deaths by infant's sex and age in days.

5 SURVIVAL MODELS

As already mentioned, the analysis reported here is one of five studies sharing the same theoretical and methodological design. The latter is discussed in detail in Quaranta (2018b). In each study analysis was undertaken in two stages: first analysis using a model common to all five projects, were applied. These were designed to be consistent across the regions and databases involved. The results of the comparison between the regions can be found in Quaranta et al. (2017). Each study then applied their own additional models to extend their analyses. In our study we undertook additional analysis which we hoped would give us a better understanding of the strong association between fertility and mortality described earlier. We used event-history methods in both stages of the research. Each child in the third generation of our sample population, that is the offspring of all second-generation mothers, was followed from birth until the age of 12 months. We then calculated a Cox proportional hazard model to predict the chances that an infant would die before, or at, the exact age of one. In order to include excess unexplained variability, such as an unobserved group effect common to infants born to the same mother, we also considered two Weibull parametric survival models, one which shared frailty amongst mothers in the first generation and one which shared it amongst mothers in the second generation.

In Table 2 descriptive statistics for the variables included in the models common to all teams in the collaborative project are presented. Our primary explanatory variable is the number of infant deaths experienced by first generation mothers, differentiating between those who experienced no such deaths (category 'zero') and those who experienced either one, or two or more. We expected the number of births borne by mothers in the first generation to affect the number of infant deaths they would experience and constructed another categorical variable to control for this; using four categories: '2', '3', '4-6' and '7+'births.

Table 2 *Descriptive statistics, sample population, Troms province, 1845-1924*

	n	Percent	Mean	SD	Min	Max
First Generation						
Number of infant deaths experienced						
0	2,027	57.63				
1	971	27.61				
2+	519	14.76				
Number of children borne						
2	214	6.08				
3	270	7.68				
4 to 6	1,228	34.92				
7+	1,805	51.32				
Total N of first generation women	3,517	100				
Second generation						
Age at birth of child						
15-24	5,727	21.87				
25-35	13,711	52.37				
35+	6,743	25.76				
Total births	26,181		6.65	2.97	1	18
Third generation						
Female	12,731	48.63				
Male	13,450	51.37				
Year of birth			1893.52	18.96	1844	1924
Birth year			14.99	18.97	-34.40	45.97
Birth order of the child						
1	5,496					
2	4,527					
3	3,857					
4 to 6	7,971					
7+	4,330					
Total N of children in third generation	26,181	100				

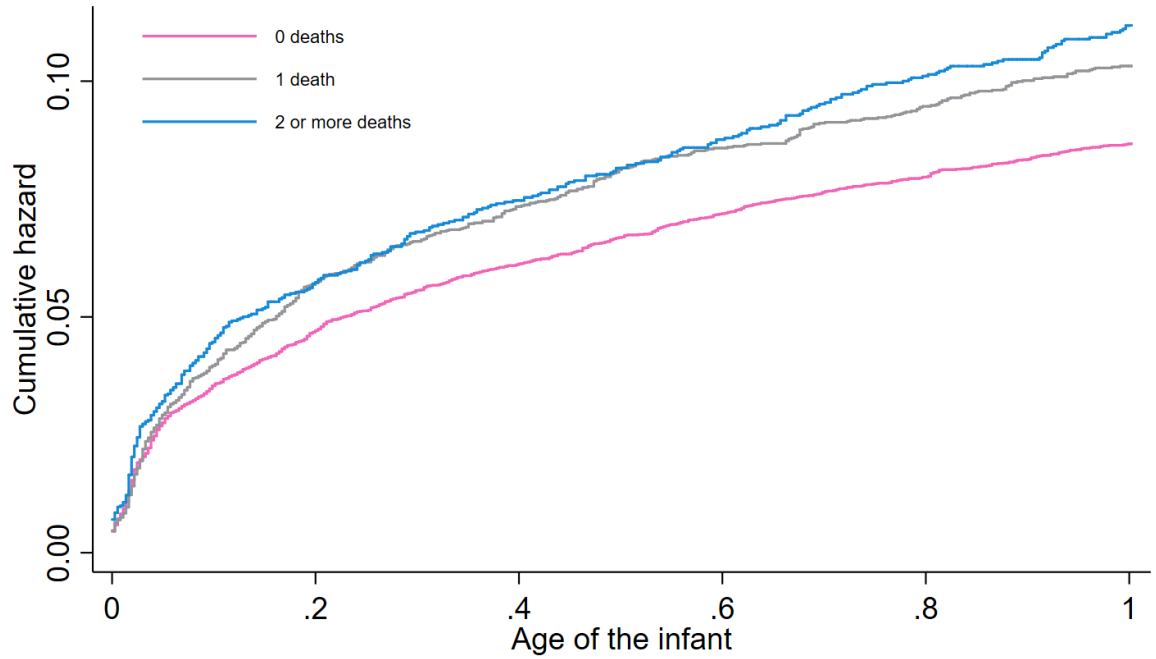
Source: HPR dataset Troms 2017 (IDS-version).

When considering the experience of the second generation, a categorical variable was created, to differentiate between those who gave birth aged 'younger than 25', '25-35' and '35 and older'. A mother's age at giving birth to a child affects the risk of that child dying during the first year of life, although not in a linear way. Usually very young and 'elderly' mothers at the extremes of the reproductive age range tend to have an increased risk of experiencing at least one infant death (Knodel & Hermalin, 1984).

When considering the children of second generation mothers, an individual-level dummy variable was included to denote the sex of the child; 1 if male, 0 if female. This is because genetic disadvantages mean that boys are more likely to die during the first year of life. Each child's birth year was also included.

As we have seen, an infant's survival chances have been found to be related to his or her rank in the birth order so we would expect the more older siblings a child had, the higher risk he or she ran of dying. A parity variable is therefore included in the models shown in Table 2.

Figure 4 *Nelson-Aalen cumulative hazard estimate of infant mortality by age since birth, amongst the grandchildren of first generation women who had experienced 0, 1 or 2+ infant deaths, Troms province, 1845-1924*



Source: HPR dataset Troms 2017 (IDS-version).

Figure 4 shows a Nelson-Aalen graph depicting the association between the different categories of infant mortality experience by first generation mothers (the loss of 0, 1 or 2+ children) and the cumulative hazard of the risk of an infant death occurring amongst their daughter's children between the exact ages of 0 and 1. In the first few weeks after birth, the cumulative hazard amongst the grandchildren of those first generation mothers who had had two or more infant deaths is only marginally higher than the hazard associated with the grandchildren of first generation mothers who had experienced 0 or 1 infant deaths. However, after the initial weeks, the hazards for the grandchildren of first generation mothers experiencing 1, or 2+ infant deaths take more or less similar paths, both diverging from the hazard for the grandchildren of first generation mothers who had 0 infant deaths. When the infants reach about 7 months of age and beyond the hazard for the grandchildren of first generation mothers losing 2+ children are higher than that for the grandchildren of first generation mothers losing just 1 child. Due to the non-proportional association between risks for the grandchildren of first generation mothers in the 1 and 2+ infant death categories, the Nelson-Aalen graph suggests a violation of the proportional hazards assumption. In contrast, when we calculated Schoenfeld residuals, which allow us to test the proportional hazards for all the individual covariates, they did not show any proportional violation (these results have not been shown). In addition, given that the hazards associated with first generation mothers who experienced 1 and 2+ infant deaths follow each other quite closely across the entire first year of life in Figure 4, and that the hazards (HR) given in Table 3 for our primary explanatory variable follow a similar trajectory, we have ignored the non-proportionality suggested by Figure 3.

Table 3 shows the results from the survival models. The infant mortality experience of first generation mothers were related to the infant mortality risks among the offspring of their surviving daughters. When we control for basic demographic factors, such as the number of children borne by the first generation mothers, the 10 year age group in which mothers in the second generation gave birth to a child, and the characteristics of that child such as sex, parity and date of birth, those daughters whose mothers had experienced 1 infant death were faced with a 21 per cent higher risk of experiencing an infant death amongst their children than the daughters of first generation women in the 'zero-death' reference category. For daughters whose mothers had experienced two or more infant deaths the risk was 28 per cent higher than the reference category. Maternal effects were also found to some extent, in that second-generation mothers in the youngest age category had a higher, and statistically significant, risk of experiencing at least one infant death than mothers in the same generation aged 25-34. Furthermore, higher parity births amongst the third generation had a lower risk of infant mortality,

than first born children, suggesting that the latter were particularly disadvantaged. The two Weibull models, one with shared frailty on the mother and the other with shared frailty on the grandmother, show similar results to those of the basic Cox proportional hazard model (Table 3).

Table 3 *Intergenerational transmissions in infant mortality, survival models, Troms province, 1845-1924*

	Cox model		Weibull model mother shared frailty		Weibull model grandmother shared frailty	
	HR	**p-value**	**HR**	**p-value**	**HR**	**p-value**
N of infant deaths experienced by the first generation						
0 (ref.)	1.000	ref.	1.000	ref.	1.000	ref.
1	1.211	0.000	1.216	0.001	1.212	0.002
2+	1.282	0.000	1.282	0.001	1.284	0.001
N of births borne by the first generation						
2 (ref.)	1.000	ref.	1.000	ref.	1.000	ref.
3	0.939	0.642	0.896	0.490	0.899	0.487
4-6	0.933	0.531	0.916	0.500	0.914	0.474
7+	0.897	0.324	0.875	0.302	0.867	0.255
Sex of child in third generation						
Female (ref.)	1.000	ref.	1.000	ref.	1.000	ref.
Male	1.049	0.278	1.042	0.364	1.043	0.348
Birth order of child in third generation						
1 (ref.)	1.000	ref.	1.000	ref.	1.000	ref.
2	0.750	0.000	0.744	0.000	0.746	0.000
3	0.839	0.025	0.831	0.020	0.832	0.020
4-6	0.851	0.026	0.833	0.014	0.839	0.017
7+	0.949	0.570	0.875	0.176	0.901	0.278
Birth year of child in third generation	0.987	0.000	0.987	0.000	0.987	5.460
Age of mother at birth of child in third generation						
15-24	1.169	0.014	1.163	0.022	1.173	0.014
25-34 (ref.)	1.000	ref.	1.000	ref.	1.000	ref.
35-50	1.033	0.614	1.078	0.262	1.062	0.365
Intercept			0.125	0.000	0.123	6.141
Frailty variance			0.616	0.000	0.372	3.194
N of children in third generation	25,730		25,730		25,730	
N of infant deaths in third generation	2,058		2,058		2,058	

Source: HPR dataset Troms 2017 (IDS-version)

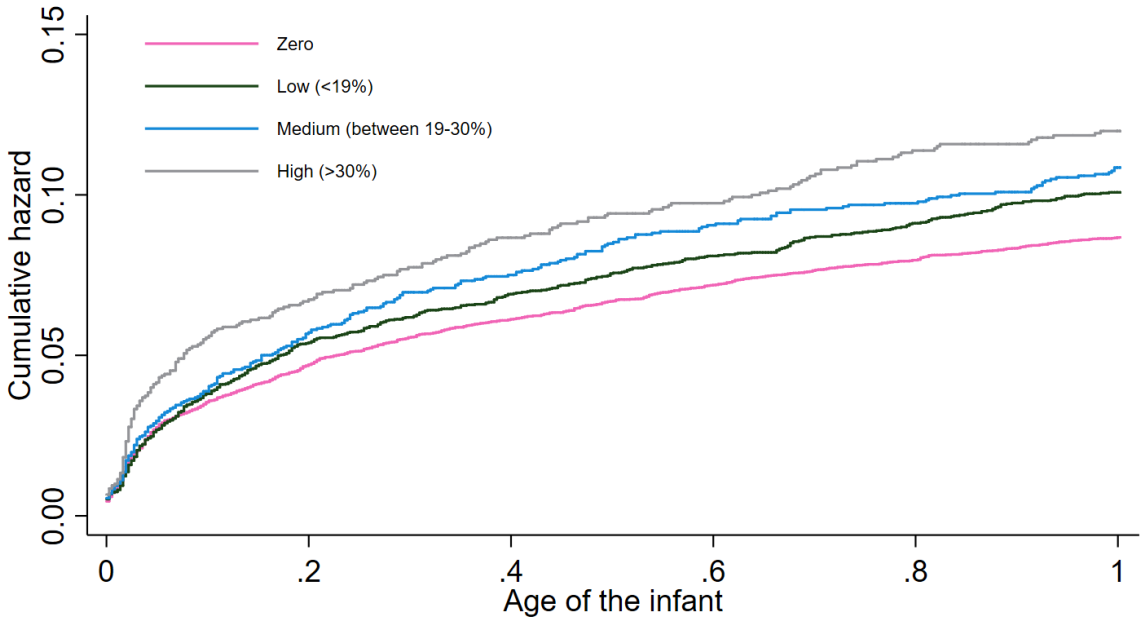
Checks were performed to test the robustness of our data selection and the construction of the variables included in our models. In addition to the Weibull models shown in Table 3, five additional Weibull models with shared frailty on the mother were estimated; the results are available on request. The additional models were run to see whether the results were sensitive to the restriction of the selection of infants to those whose grandmothers were observed reaching their 50th birthday (model i); to those whose grandmothers were observed either reaching their 50th birthday or dying after that date (model ii); to those whose grandmothers are observed reaching their 50th birthday and their husbands also observed until her 50th birthday (model iii); to those whose grandmothers were observed reaching their 50th birthday and the dates of birth of all her children were known (model iv); and to those whose grandmothers were observed until their 50th birthday and all their children were in observation until either they died aged less than 1 or were observed reaching their first birthday

(model v). In the last model a child was assumed to have reached its first birthday if it was observed in any source after that date. These sensitivity analyses showed that those children whose maternal grandmother had experienced 2 or more infant deaths had between a 26 and a 42 per cent higher risk of dying in infancy than the grandchildren of women in the zero-infant death category, a finding which was statistically significant in all five models. For children whose maternal grandmothers had experienced just one infant death, the results from the models suggested that they ran a 20-27 per cent higher risk than the grandchildren of women in the reference category, a finding which was statistically significant in model ii and only slightly above the threshold for statistical significance in models i, iii, and iv.

6 AN EXTENDED SURVIVAL MODEL

Given the historical setting described in part 2, it would greatly help our analyses of the intergenerational effects on infant mortality if we could take differences in socio-economic status (SES) into account, and also adjust our measures to allow for seasonal and annual variation in income. It would be possible to make the latter adjustments by constructing proxy variables based on the yearly 'Reports on the State of Health and Medical Conditions in Norway', which are available from 1853 onwards. However, while the Norwegian Historical Population Register (HPR), on which the present study is based, does contain information about individual, mainly male, occupations, culled from the population censuses, there were too many obstacles to the construction of occupational categories to allow us to include SES differences in the current study.

Figure 5 *Nelson-Aalen cumulative hazard estimate by mean infant mortality of first generation mothers*



Source: HPR dataset Troms 2017 (IDS-version).

Having established a strong association between fertility and mortality in the descriptive statistics (Section 3) we applied a more dynamic approach by extending our models to include the infant mortality rate (expressed as the number of infant deaths per 100 births) experienced by the first-generation mothers. The women were divided into four risk categories: those who had experienced no infant deaths (the 'zero risk' category), those with less than 19 infant deaths per 100 births ('low risk'), those with between 19 and 30 deaths per 100 births ('medium risk') and those who had lost more than 30 per cent of their infants through death ('high risk').[2] The maternal predictors described in the

2 A similar approach was used in Edvinsson et al. (2005), with high-risk families defined as families experiencing an infant mortality rate of more than 300 per 1000 births.

previous section were all included in our extended model, apart from the number of births borne by the first generation mothers. As stated in Section 3, the proportion of families at 'high risk' of infant mortality began to decline from around 1880, and we were interested to evaluate this change when intergenerational effects were measured. Consequently, children's birth dates were excluded from the new model but a dummy predictor was included to denote births taking place in the period prior to and the period after 1880.

As expected, Figure 5 shows that the cumulative hazard in infant mortality amongst the grandchildren in the third generation increased steadily according to whether their grandmothers were classified as having had 'zero', 'low', 'medium' or 'high' rates of infant mortality.

Table 4 *Intergenerational transmissions in infant mortality, extended survival model, Troms province, 1845-1924*

	Cox model	
	HR	p-value
Mean number of infant deaths per birth experienced by first generation women:		
'Zero' (ref.)	1.000	ref.
'Low': mean <0.19	1.168	0.004
'Medium': mean >0.19 & <0.30	1.230	0.002
'High': mean >0.30	1.353	0.000
Sex of child in third generation:		
Female (ref.)	1.000	ref.
Male	1.048	0.289
Birth order of child in third generation:		
1 (ref.)	1.000	ref.
2	0.746	0.000
3	0.830	0.018
4-6	0.850	0.013
7+	0.948	0.376
Time period:		
before 1880 (ref.)	1.000	ref.
after 1880	0.655	0.000
Age of mother at birth of child in third generation		
15-24	1.169	0.018
25-34 (ref.)	1.000	ref.
35-50	1.035	0.774
N of children	25,730	
N of infant deaths	2,058	

Source: HPR dataset Troms 2017 (IDS-version)

The mortality history of a mother's own infants is therefore a predictor of the survival chances of her daughters' infants. Once maternal effects, the characteristics of the grandchild, and the time period, were taken into account, daughters whose mothers had lost a 'high' proportion of their infants before their first birthday were 35 per cent more likely to have lost an infant than women whose mothers had lost fewer children. Both the shared model and our extended model show that it was the children of the youngest mothers and first-born children who were more likely to die. Our results also indicated that children born after 1880 were 35 per cent less likely to die in infancy compared to those born before 1880.

7 DISCUSSION AND CONCLUSION

This paper has reported on one of five studies analyzing the intergenerational transfer of infant mortality using a common suite of programmes, created for use with data stored in IDS format. These programmes were written by Luciana Quaranta (2018b) and will be available via the *Historical Life Course Studies* website. The other four papers arising out of the collaborative project consider the intergenerational transfer of infant mortality in 19th century northern Sweden (Broström, Edvinsson, & Engberg, 2018), 18th to mid-20th century southern Sweden (Quaranta, 2018a), Zeeland 1833-1900 (Van Dijk & Mandemakers, 2018), and 19th and early 20th century Antwerp (Donrovich, Puschmann, & Matthijs, 2018).

All five participating research teams used Quaranta's programmes to run the same models to estimate the effect in their datasets of the number of infant deaths experienced by a first-generation mother on the probability that one of her daughters', would lose a child in infancy. Each team then extended their research by designing their own models, and we chose to examine the association between fertility and mortality in the Troms dataset more closely.

Both the shared models and our extended model found evidence of an intergenerational transmission of infant mortality risk down the maternal line in the Norwegian data. In our extended analysis, the results suggest a strong intergenerational transmission in the risk of death amongst infants born to daughters whose mother had lost more than 30 per cent of her children in infancy, compared to infants borne by daughters whose mothers had experienced zero infant deaths. Significant associations were also found amongst the grandchildren of first generation women who had experienced 'low' and 'medium' levels of infant mortality. In addition, higher risks were also associated with first born children, particularly those borne by second generation mothers in the 15-24 age group. Overall, infant mortality tended to cluster in particular families, which meant that the majority of women in both generations experienced no infant death at all. The models which were run do not allow us to elaborate on *why* there was a correlation between the rates of infant mortality in the different generations. However, given the historical context and our descriptive analysis, the models can provide a starting point from which to make some qualified speculations.

Some twenty-first century studies have also found a higher risk of infant death among the first-born children of mothers aged less than 25 years old, and unfavorable socioeconomic conditions and physiological immaturity have been offered as possible explanations (Alam, 2000). In our sub-sample from nineteenth century Norway, the mean age at first birth amongst our second-generation mothers was 24.8 years. Physiologically, this would not be regarded as particularly young, as by this age a woman's body should be mature enough for pregnancy, assuming that she had reached menarche around the age of 15 or 16. On the other hand, having a young mother might be a proxy indicating the family's unfavorable socioeconomic status, which would have made first born babies particularly vulnerable to mortality.[3] Doctor Schjelderup noted in the medical report for Trondenæs district in the southern part of Troms in 1879, that he was worried about the increase of easy virtue among the younger generation, which he saw as leading to marriages that would give any children a rough start in life: 'Young boys and girls get married without any plans on how to support a family, and the number of poor cottars and tenants increases from one year to the other […]. 'Perhaps we may add 'easy virtue' to the basket of cultural 'preferences' handed from mothers to daughters, along with norms regarding age at first birth, family size and childcare practices.

Both the descriptive analysis and our extended model indicate that there was change over time, with second generation women whose mothers were in the 'low', 'medium' and high infant mortality categories experiencing a 35 per cent decrease in the likelihood of losing an infant in the post-1880 period compared to the pre-1880 period. By 1915-24, only 8 per cent of the families in Troms were 'high infant mortality' families, compared to 40-45 per cent in the first 50 years of the 19th century, although there had been no consistent decline until around 1880. What may have contributed to this change? Inspired by the British Public Health Act of 1848, Norway implemented its own Public Health Law in 1860 (Lov av 16. mai 1860 om Sundhedscommissioner m.v.). This law was framed in two separate sections, each with its own aims and targets. The first part announced the establishment

3 Unfortunately, we do not have the occupational variable included in the IDS version of the HPR-database for the moment. Preliminary analysis shows that occupation of the father was only given for about 40 per cent of the children at risk. We are working to create a dynamic occupation variable based on events during an individual's lifespan.

of a Health Commission to be located in each medical district; it was stated that the Commissioners were to focus their attention on 'the health conditions of the locality and on whatever can affect them […]' (*Sundhedscommissioner m.v.,* para. 3, our translation). The second part of the Public Health Law then concentrated on measures relating to epidemic and contagious diseases. Based on the annual medical reports, previous researchers have argued that the work of the Health Commissions on preventive measures, such as campaigns to improve sanitation and standards of hygiene had minimal effect before the 20th century, certainly in rural areas (Schiøtz, 2010). On the other hand, Hubbard (2002) has found that public health interventions effectively reduced mortality rates in Norway's three largest cities; a decline driven by a decrease in deaths caused by the major childhood diseases such as whooping cough, measles, scarlet fever and diphtheria.

We know from Official Statistics of Norway that children in the 1-4 age group were at serious risk of dying from epidemic diseases until 1881-85 when mortality reached a peak that was caused by the conjunction of two exceptionally aggressive epidemics, one of diphtheria and one of scarlet fever. After this peak a remarkable decline set in and within 10 years child mortality had fallen by 42 percent. We have yet to ascertain whether this decline can be seen in Troms, but it is tempting to suggest that the decline in the proportion of 'high risk' families amongst women in the second generation was related to a general decline in the virulence of childhood diseases, which would also have benefitted the survival chances of more vulnerable infants. In future research we intend to build models in which infant deaths occurring during the first week, as well as, other neonatal and post-neonatal deaths are considered as separate categories. This will allow us to differentiate more clearly between deaths associated with endogenous causes and those associated with exogenous causes, and we should therefore be able to gauge whether the diminishing virulence of childhood diseases played a significant part in the changes in intergenerational transfer of infant mortality. We will also consider the spatial clustering of infant mortality and consider the role a shared environment might play in the transfer of infant mortality risk between generations.

Overall, the collaborative project using IDS in a number of historical contexts has been very valuable, allowing all the participating teams to share their knowledge of the IDS and to contribute to the design of the research models. Since the HPR has still to be fully integrated into IDS, being part of the collaborative project has provided an opportunity to identify the challenges which may be encountered in this process, something which has been most helpful. Undoubtedly, having multiple datasets in IDS format will be a very valuable resource for international comparative research.

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