DEMOGRAPHIC RESEARCH
A peer-reviewed, open-access journal of population sciences

DEMOGRAPHIC RESEARCH

VOLUME 38, ARTICLE 2, PAGES 37−94
PUBLISHED 4 JANUARY 2018
http://www.demographic-research.org/Volumes/Vol38/2/
DOI: 10.4054/DemRes.2018.38.2

Research Article

Historical reproductive patterns in developed countries: An aggregate-level perspective

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Demographic Research: Volume 38, Article 2
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Historical reproductive patterns in developed countries: An aggregate-level perspective

Jesús J. Sánchez-Barricarte[1]

Abstract

BACKGROUND

One of the fundamental arguments sustaining the classical demographic transition theory was that couples wanted to have a given number of surviving children, not a specific number of births. However, this cornerstone of transition theory came in for severe criticism in the wake of the results published in many studies linked to the Princeton European Fertility Project (PEFP). In recent years, studies using longitudinal microdata have made important contributions towards clarifying the relationship between mortality and fertility during the transition.

OBJECTIVE

We will show that aggregated data (from both the national and the provincial sphere) can lead to conclusions similar to those obtained at micro-level.

METHODS

Employing information from 25 developed countries, this article analyzes trends in net reproduction (rather than just the intensity of births) over a long period of time. We also quantify in detail the different influences of marital fertility, mortality, and nuptiality on historical developments in net total reproduction.

RESULTS

Our analysis reveals a great diversity in the reproductive patterns followed in different countries in the process of regulating the total number of births. We also detect the existence of a nonhomogeneous effect of mortality on net reproduction during the demographic transition.

CONCLUSIONS

There is little point in analyzing fertility trends if we leave out the mortality scenario that forms the background to these tendencies.

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CONTRIBUTION
The results of this study using aggregated data (covering longer periods of time and larger geographical areas) are fully in line with those of recent projects using microdata from family reconstructions.

1. Introduction

It is generally accepted that before the demographic transition, people's reproductive behavior was conditioned by cultural and social factors: The total number of births in a given society was regulated by the age of access to marriage or the percentage of young people who could afford to marry. As the transition set in, decisions about reproduction began to have a more individual, family-orientated background. In other words, the decision as to the number of children to have came to be influenced more by the family's circumstances than by social expectations (Reher and Sandström 2015; Reher et al. 2017).

Until recently it was impossible to test empirically whether couples actively took decisions during the demographic transition, particularly in view of the changes in mortality, which are likely to have had a major impact on reproductive behaviors. It is true that the founding fathers of demographic transition theory always regarded mortality as the key factor that triggered the decline in fertility during the late 19th century (Notestein 1945; Davis 1963), but this was more of a supposition than a demonstrable fact. One of the fundamental arguments sustaining the classical demographic transition theory was that couples wanted to have a given number of surviving children, not a specific number of births. However, this cornerstone of transition theory came in for severe criticism in the wake of the results published in many studies linked to the Princeton European Fertility Project (PEFP) (Knodel 1974, 1978; Lesthaeghe 1977; Matthiessen and McCann 1978; van de Walle 1986). However, some experts continued to stress the important influence of mortality on the birth rate (Knodel 1988; Kirk 1996; Haines 1998; Galloway, Lee, and Hammel 1998).

According to Reher and Sandström (2015: 21), this division over such a fundamental issue was due to the fact that "the mechanisms whereby mortality change intervened in reproductive decisions are not well understood because of a lack of requisite individual level data." One consequence of the disappointing results obtained by the Princeton European Fertility Project was precisely that over the following decades there was a genuine explosion in studies using individual longitudinal data obtained by family reconstruction techniques (Alter 1988; Bengtsson and Dribe 2006;

Knodel 1988; van Bavel 2003, 2004; Reher and Sanz-Gimeno 2007; van Bavel and Kok 2010; Reher et al. 2017).

Information about individuals is certainly richer and more diverse than aggregated data from large geographical areas, but it is subject to considerable restrictions because it is practically impossible to apply these techniques over long periods of time or large geographical areas. Even if the financial, material, and human resources are available to undertake such a colossal task, the doubt always remains as to whether the information obtained for the village (or group of villages) is really representative of the country where that village is situated. In short, it is hard to construct general explanatory theories about demographic behaviors on the basis of the patterns observed in a few villages. To this we must add the fact that it is very difficult to perform family reconstructions for cities, or even for towns. Family reconstitutions have been undertaken only rarely in urban settings due to the high mobility of historical urban populations. However, historically, urban populations exerted an influence on national demographic trends (Davenport 2016). The swift urbanization process in Western countries during the demographic transition cannot be ignored in historical studies of reproductive behavior, and so it is necessary to augment and complement the results of family reconstruction studies by using other analytical approaches that allow us to contrast demographic patterns in urban and rural areas. In other words, the rich data provided over recent decades by microanalyses based on family reconstruction need to be complemented by the results of studies based on aggregated data.

One of the contributions of the present study is precisely its use of a large number of countries over a lengthy historical period. We show that aggregated data (from both the national and the provincial sphere) can lead us to draw conclusions similar to those obtained at micro-level. The structure of this paper is as follows. Section 2 explains our methodology for measuring net reproduction (marital and total). Sections 3 and 4 provide a descriptive analysis of historical developments in net reproduction. In section 5 we quantify the influence on net total reproduction of marital fertility, mortality, and nuptiality in each country. Finally, in section 6 we analyze the changing effect of mortality on net total reproduction over the demographic transition period.

2. Methodology and data

Traditionally, studies seeking to understand and explain the historic decline in fertility have made use of indicators which reflect the relative intensity of births: crude birth rate (CBR), total fertility rate (TFR), general fertility rate (GFR), Princeton overall fertility index I_f,[2] etc. Even much recent historical research that analyzes several countries at a time (Ángeles 2010; Herzer, Strulik, and Vollmer 2012; Murtin 2013) still confines itself to using these indicators. However, historically speaking, the total number of children born in the Western world has depended not only on how many children married couples had on average but also on what percentage of women actually married, since the proportion of illegitimate births was very low. Figure 1 shows that, except in the case of Iceland, the percentage of births outside marriage was hardly ever above 10% before 1980. That is, access to marriage was traditionally a key mechanism in the process of regulating total fertility.

Trends in nuptiality (I_m) during the demographic transition differed from one country to another (for example, Sweden, Denmark, Norway, Canada, and Belgium saw much greater increases than Spain, Italy, Finland, and Austria over the 19th and 20th centuries). If we want to identify the factors which led couples to have fewer children, using fertility indicators that measure the total birth rate is not the best strategy; rather, we should neutralize the effect of nuptiality by using indices which only measure marital fertility.

However, although important, distinguishing between marital and total fertility is insufficient: merely analyzing the intensity of births, total or marital, is not the most appropriate method. Parents' main aim as far as reproduction is concerned was, and still is, to attain a number of surviving children who will reach adulthood, not to have a specific number of births. According to classic demographic transition theory, mortality change was a key factor in triggering the fertility decline, "based on the supposition that couples generally desired a given number of surviving children, and that fertility control was, at least originally, an effort to restore the balance in the family size that had been upset by declines in childhood mortality" (van de Poppel et al. 2012: 300).[3]

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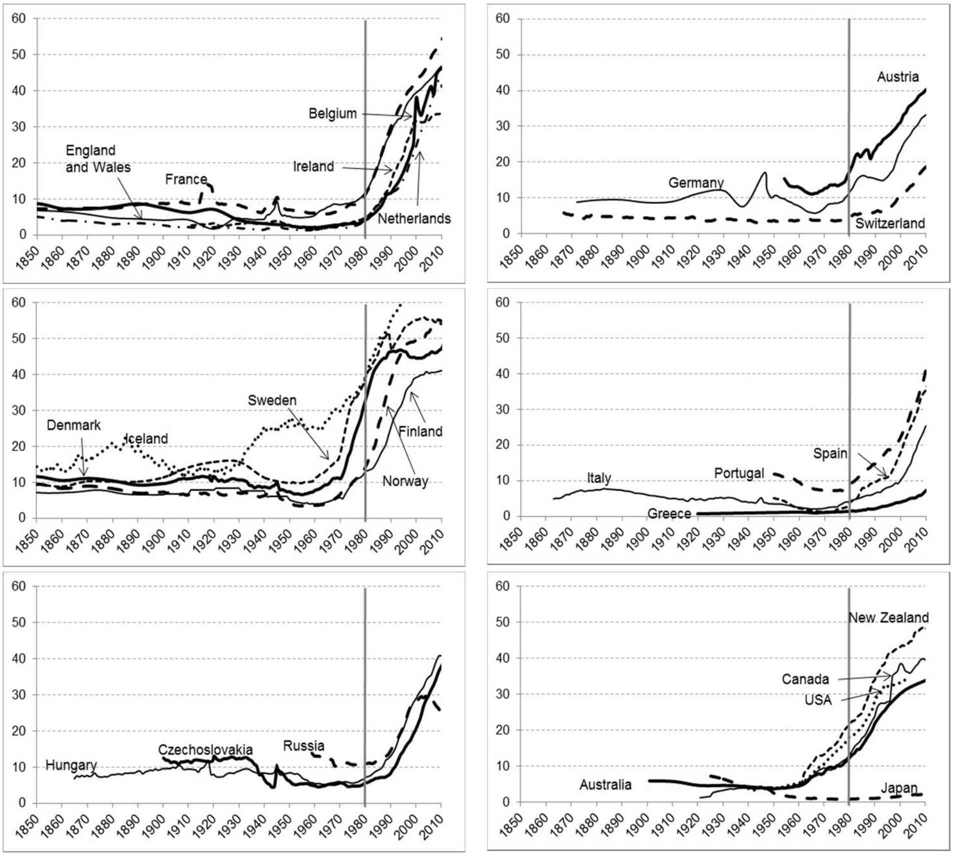
[2] I_f is the ratio of the actual number of births to the hypothetical number if women were subject to the married Hutterite fertility schedule (Coale and Watkins 1986: 153–162).

[3] Generally, three different mechanisms are outlined to explain how the drop in childhood mortality may have affected the fertility rate in historical times (Palloni and Rafalimanana 1999). One of these has a biological basis: When a baby dies, breastfeeding has to be stopped, which means that the infertile postpartum period comes to an end (Knodel and van de Walle 1967). The second has to do with individual effects: When a couple aims to have a specific number of surviving children, the early death of a child will prompt parents to have another child to replace the one that was lost. Finally, another mechanism operating at the community level has been mentioned: the decline in childhood mortality may reduce fertility by changing the unwritten rules of the community and altering the social and economic institutions. For example, institutional structures (such as the system of inheritance) are placed under pressure as a result of raised life expectancy, leading to a process of adaptation in which birth control becomes more acceptable (Reher and Sandström 2015).

Figure 1: Percentage of births outside marriage



Source: See Appendix.

Historically, when mortality rates were high, fertility and mortality were closely bound together, so the former should not be analyzed without taking the latter into account. Young, recently married couples had direct experience of the mortality in the region where they lived. Most probably there was also some kind of community wisdom and knowledge about how many births were necessary to allow x number of children to survive to adulthood. Some demographers have called this the 'social effect': Societies have their own rules and customs for ensuring a balance between mortality and fertility rates. Wrigley (1978) asserts that there is an "unconscious rationality" which guarantees the wellbeing of the group. The relationships between mortality and fertility and between nuptiality and mortality may have been adaptation mechanisms used by societies in historical times to regulate population growth. Many studies in historical demography using micro-level data after the Princeton Project have demonstrated replacement of deceased children with individual fertility life-course data (Bengtsson and Dribe 2006; Knodel 1988; van Bavel 2003, 2004; Reher and Sanz-Gimeno 2007; van Bavel and Kok 2010; van Poppel et al. 2012; Reher and Sandström 2015; Reher et al. 2017).

To conduct comparative studies between different countries over long periods of time it is also necessary to cancel out the effect of mortality on fertility, so we need an indicator which measures the number of surviving children in order to discover which factors might have a bearing on the long-term decline in reproductive behavior. It would be pointless to compare the intensity of births in different years or countries where the survival probabilities were very different. The net reproduction rate (NRR) better represents the extent of departure from the long-run historical equilibrium between mortality and fertility (Cleland 2001: 62). The calculation of the NRR affords us an opportunity to consider variations in all three major aspects of demographic behavior: fertility, mortality, and nuptiality.

Some previous studies focus on trends in the NRR in a small number of countries (Lotka 1936; Glass 1940, 1945; Hyrenius 1951; Smith 1972; Wrigley 1985a, 1985b; Wrigley et al. 1997; Chesnais 1998; Cummins 2009; Strulik and Weisdorf 2014; Cervellati and Sunde 2015), but no systematic comparative analysis as yet exists that covers a large number of countries. It is still more difficult to find research that considers NRR levels over a long period of time in several different countries.

We were unable to calculate the NRR for all the countries in our study because most of the historical sources we consulted do not provide the necessary age-specific fertility rates (${}_nF_x$). Since the NRR is largely a function of marital fertility, nuptiality, and mortality, the available data can be simply converted into an estimate of the NRR: We propose that the indicators for the intensity of total births (total fertility rate (TFR) and the Princeton overall fertility index (I_f)) should be weighted by the probability that children would survive to age 25 (${}_{25}p_0$).[4] Thus:

$$\mathrm{TFR} \times {}_{25}p_0$$
$$I_f \times {}_{25}p_0$$

The idea of estimating the net reproduction rate by multiplying the gross reproduction rate (GRR) by the probability of survival to an age close to the mean age of childbearing has been known in demography for decades, and is explained in several

[4] Wrigley (1985b: 144) makes an estimate very close to our proposal in his historical study of fertility in the French départements.

text books (Newell 1988: 110; Hinde 1998: 187). What we are doing in the indicators we propose here is assuming 25 years to be the mean age of childbearing, and using all births rather than just female births.

As expected, and as Table 1 shows, the coefficients of correlation between these two indices and the NRR are very close to 1. Various researchers, who are listed in the Appendix, calculated the historical values of the NRR as shown in Table 1. When we correlated these values with those of the indices that we built (TFR $\times$ ${}_{25}p_0$ and $I_f \times {}_{25}p_0$) we found extremely high correlations in different countries and at different periods of time. We therefore use the indices proposed here as a reliable approximation of the historical development of the values of the NRR. We shall call these the 'indices of net total reproduction' (since they are calculated by taking into account all births, both male and female, this is the main feature that differentiates them from the net reproduction rate).

Table 1: Correlation coefficients between the net reproduction rate (NRR) and the indices TFR $\times$ ${}_{25}p_0$ and $I_f \times {}_{25}p_0$

	TFR $\times$ ${}_{25}p_0$	$I_f \times {}_{25}p_0$
Denmark (1665–1840)	0.998	
Denmark (1906–2009)	0.999	0.990
England (1541–1871)	0.998	
England and Wales (1870–2009)	0.990	0.962
France (1901–2009)	0.998	0.968
Germany (1881–2009)	0.996	0.957
Italy (1901–2009)	0.998	0.991
Sweden (1816–2009)	0.998	0.962
USA (1935–2009)	0.991	0.942

Source: See Appendix.

As we pointed out above, it is essential to neutralize the effect of nuptiality on fertility, since the intensity and calendar of marriage in the various countries in this study are very different. If we want to analyze the factors that affect reproductive decisions among married couples, we must confine our analysis to births within marriage. One way of estimating an index of net marital reproduction is to weight the Princeton marital fertility index I_g[5] with the probability of surviving to the age of 25 (${}_{25}p_0$):

$$I_g \times {}_{25}p_0.$$

[5] I_g is the ratio of the number of births occurring to married women to the number that would occur if married women were subject to maximum fertility (married Hutterite women) (Coale and Watkins 1986: 153–162).

In this way, with the historical data gathered here, we analyze the evolution of the net reproduction indices (total and marital) over a long period of time in 25 countries.

For the purposes of this study, we collected information on fertility, mortality, and nuptiality in 25 developed countries over a very long period of time: Australia, Austria, Belgium, Canada, Czechoslovakia, Denmark, England and Wales, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Russia, Spain, Sweden, Switzerland, and the United States.[6] The main line of the analysis in this article is based on national data, but we also include some analyses (tables and graphs) based on provincial data for a much smaller number of countries. In the Appendix we provide a detailed list of the large number of sources that were consulted.

3. Description of the evolution of I_g (index of marital fertility) and $I_g \times {}_{25}p_0$ (index of net marital reproduction)

In Figure 2 we can see the major differences between the indices, observing the historical development of the relative number of births (total and marital) with respect to net reproduction (total and marital). The history of the demographic transition is very different depending on which of these figures forms our starting point. For example, if we pay attention exclusively to indicators of the intensity of births, we would have to conclude that between 1800 and 1970 the marital fertility index (I_g) in France fell by 57% and the total fertility rate (TFR) by 46%. However, if we consider net marital or total reproduction ($I_g \times {}_{25}p_0$ or TFR $\times {}_{25}p_0$) we will see that the decline is much more moderate (22% and 1.5%, respectively). Arguably, the latter should be the approach in most research on historical fertility. Although it is no easy task to obtain the information needed to calculate $I_g \times {}_{25}p_0$ for earlier historical periods, the data that is available allows us to emphasize certain important aspects.

(a) Before the decline began, the values for $I_g \times {}_{25}p_0$ were generally around 0.4–0.5. We find higher values (0.5–0.6) in Western offshoot countries[7] (Canada, New Zealand, and probably also Australia and the USA).

(b) Before this index began to fall, there was a period of general growth. Often called the ‘ski–jump’ effect of the historic transition, this turnaround in net marital fertility took place during the second half of the 19th century (except in France, where it happened in the late 18th and early 19th centuries) (van de Walle 1974: 179; Dyson and

[6] We have included the largest number of countries for which we were able to find historical data of proven reliability.
[7] This term was created by the economic historian Angus Maddison (2009).

Murphy 1985). This pretransitional[8] rise led some countries to reach levels as high as those found in the Western offshoot countries. This general increase in the index of net marital reproduction was due to a rise in both marital fertility (I_g) and survival (${}_{25}p_0$) (the data from England and Wales, Norway, and Sweden is particularly revealing).

(c) Some researchers (Galor 2005a, 2005b, 2012) have repeatedly pointed out that mortality began to fall in most Western countries long before the decline in fertility. As Table 2 shows (column B – A), although the difference between the dates of the fall in mortality and the fall in marital fertility was 17 years on average, there were countries in which both fell at practically the same time, while in others it took more than three decades for the effect to set in.[9]

(d) In the period of time between the onset of the declines in $I_g \times {}_{25}p_0$ and mortality (${}_{25}q_0$) (column C – A in Table 2 and Figure 2) we can clearly distinguish two phases. In the first the initial decline in mortality was accompanied by an increase in the levels of marital fertility (I_g), which was surely due to the reduction of some of the limiting factors related to 'natural fertility' (Henry 1961) as people's health improved. Later, in a second phase (which in most countries lasted for some decades), couples began to limit their fertility to adapt to the new survival rates. However, it is very important to bear in mind that although the relative number of marital births (I_g) fell, the index of net marital reproduction ($I_g \times {}_{25}p_0$) did not; that is, couples reduced their number of births in order to adapt to the decreasing mortality rates.

When did the I_g and $I_{g25} \times p_0$ indices begin to fall? To date the onset of the decline in marital fertility, researchers involved in the PEFP chose to follow the criterion of identifying the year in which the I_g had fallen by 10% with respect to the typical plateau observed before the fall (as long as the value of I_g did not subsequently return to the level of the plateau) (Coale and Watkins 1986: 37). We followed the same criterion, but used the index of net marital reproduction ($I_g \times {}_{25}p_0$). By doing so, what we want to pinpoint is not the moment at which couples reduced the number of births, but the corresponding figure for the number of children surviving to adulthood.[10]

[8] By 'pretransitional' period we mean the period before an uninterrupted decline of 10% in the mortality rate occurred.

[9] In some countries these dates are merely indicative. If we were able to obtain earlier data it is highly likely that we would have to modify the dates of the decline in some countries (for example, Portugal).

[10] Some scholars have dropped the 10% rule (Bryant 2007; Casterline 2001) as a criterion for establishing the onset of the historic decline in fertility. We prefer to maintain this in order to bring out the fact that this was not the main mistake made by the Princeton Project: the chief problem was that it applied the indices which measure fertility rather than those which take into account the number of children surviving to adulthood.

Figure 2: Development of different demographic indicators

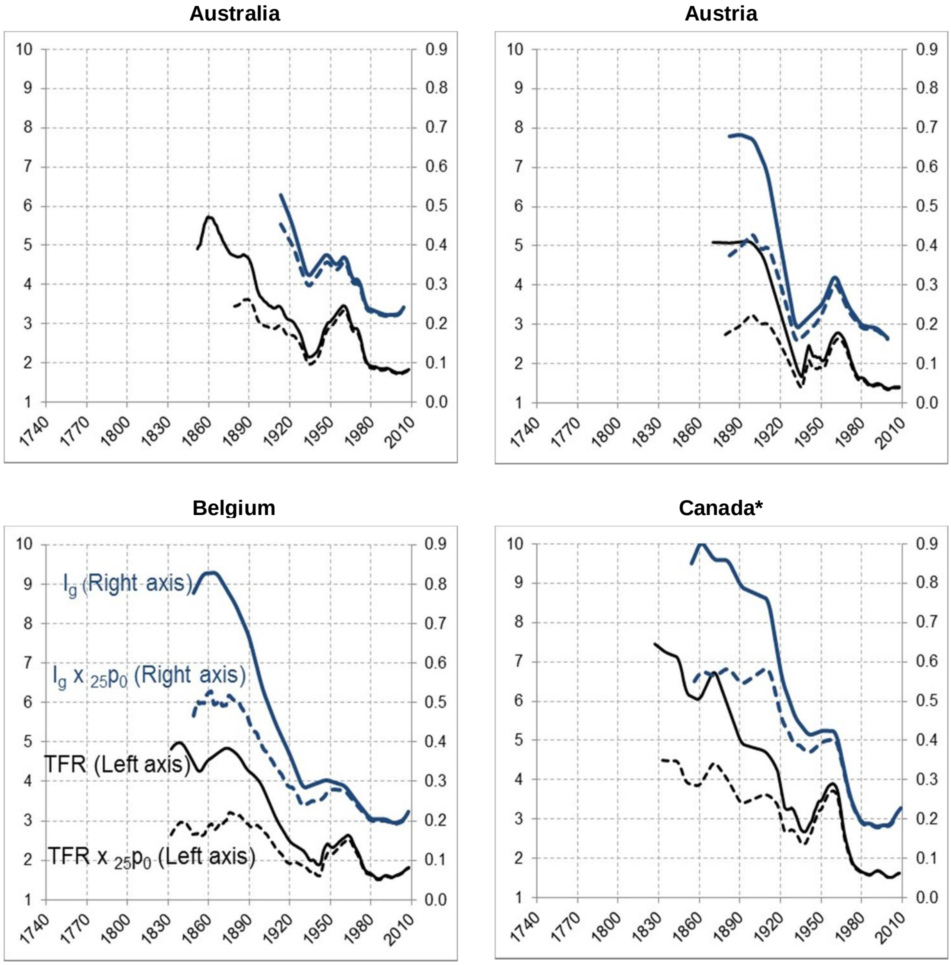
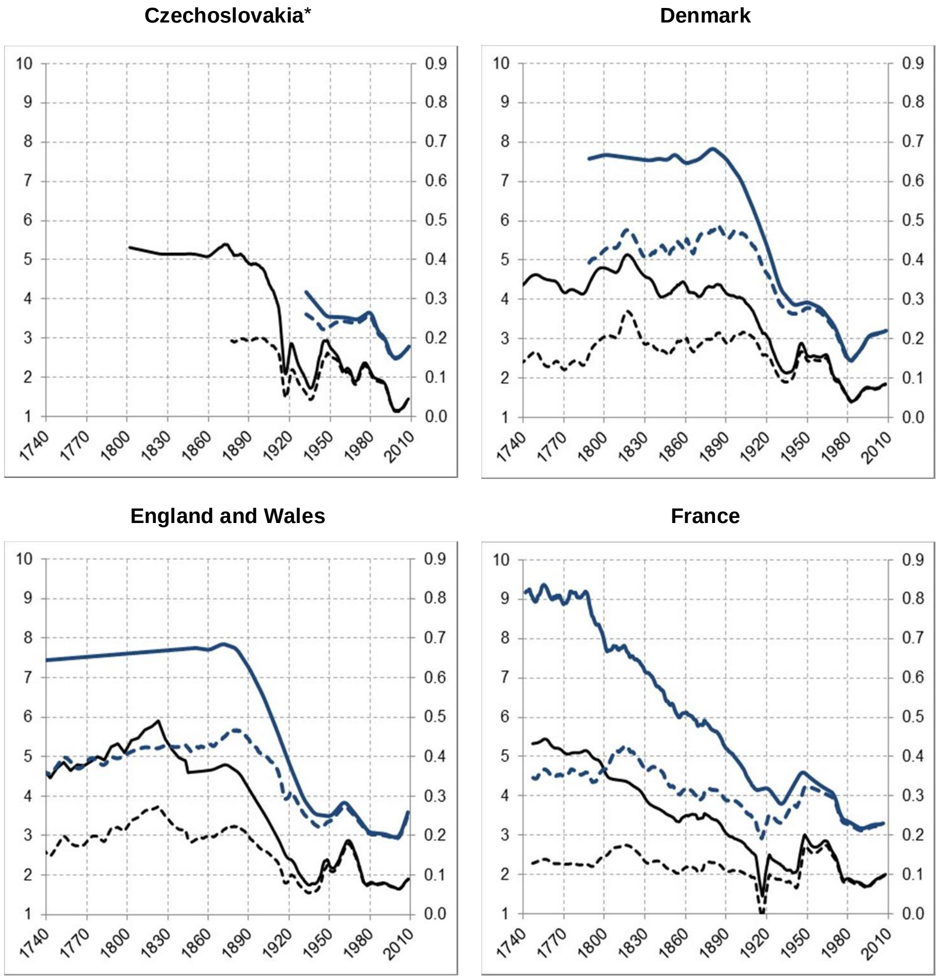


Figure 2: (Continued)



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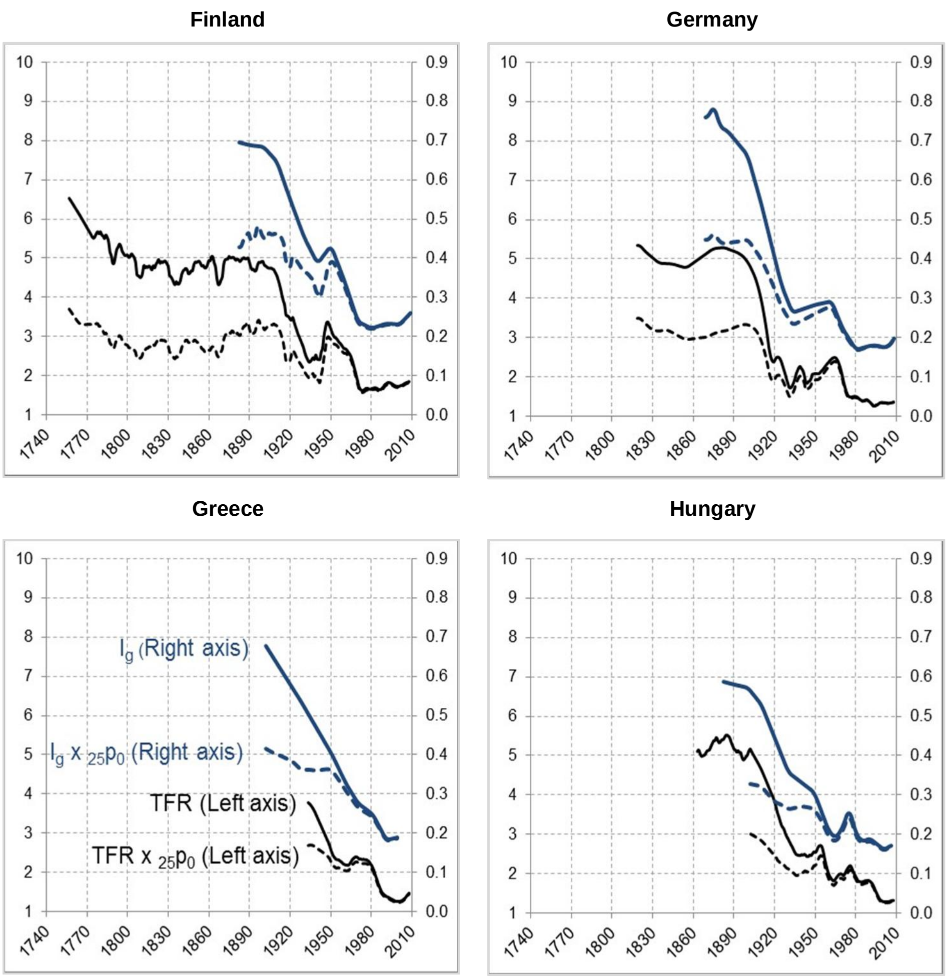

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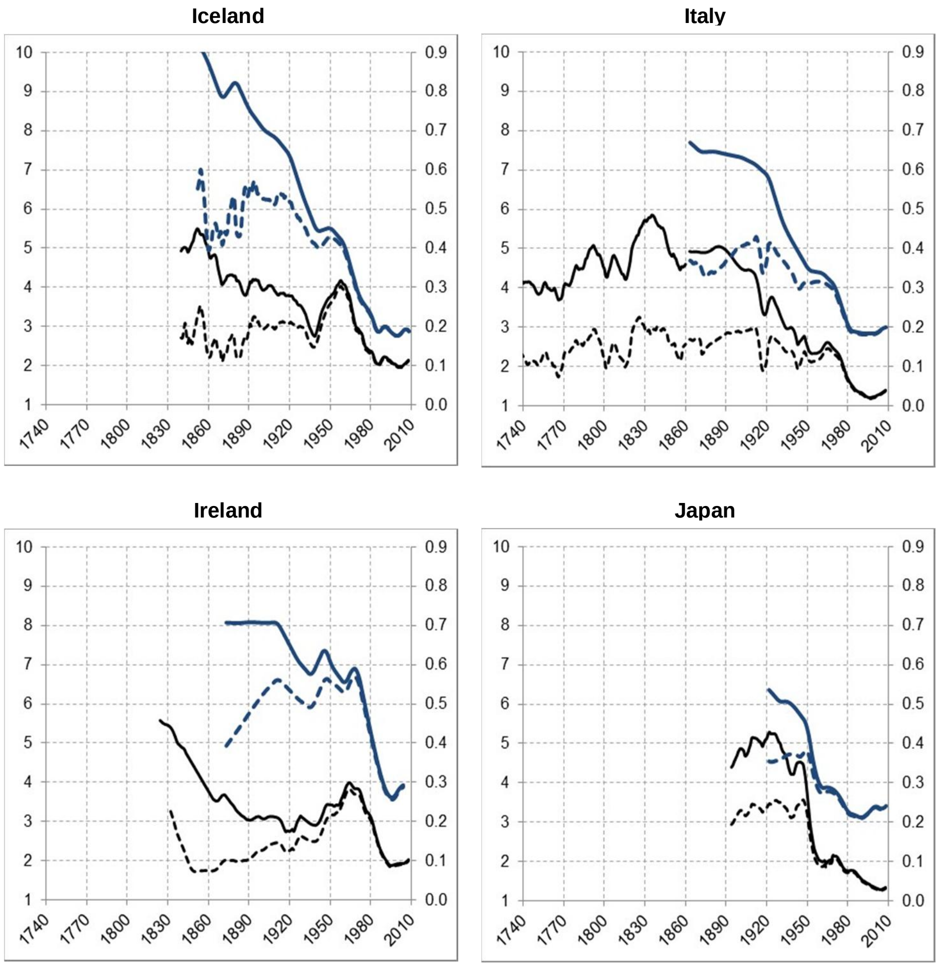

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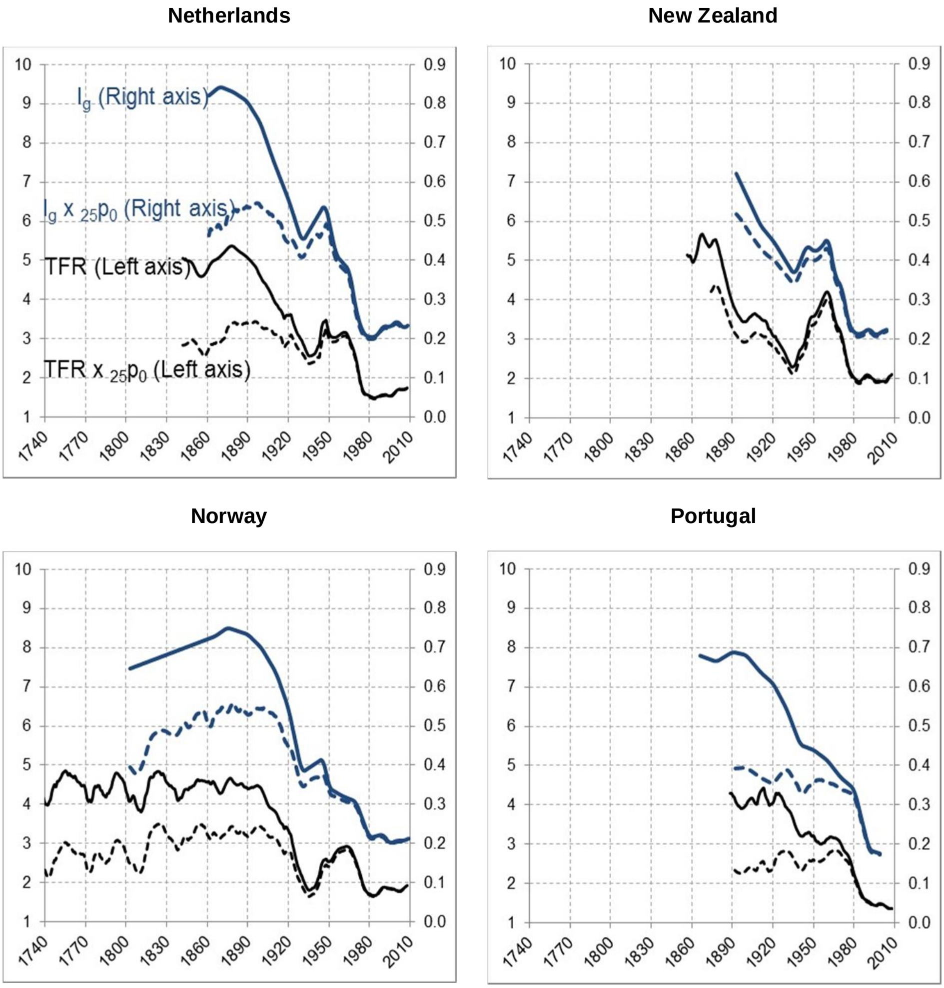

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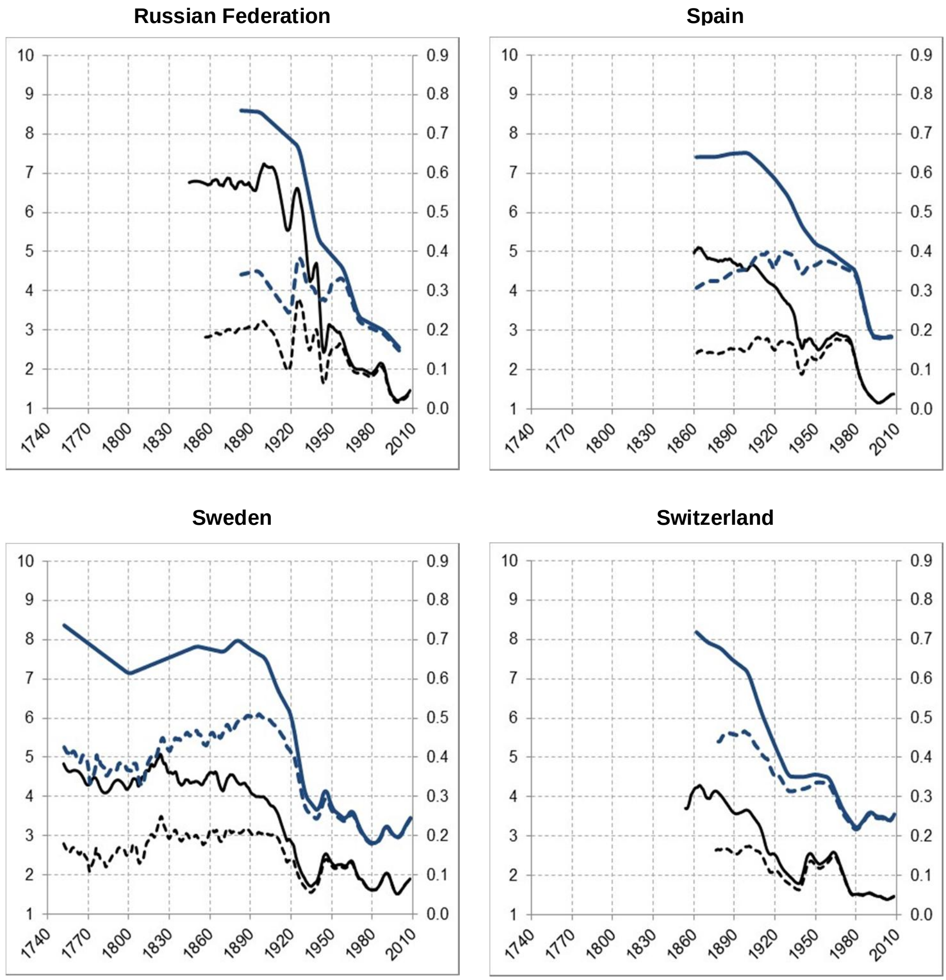
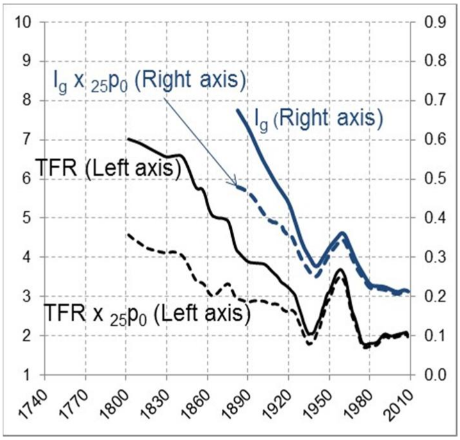


Figure 2: (Continued)

United States



Note: * The Canadian data from before 1921 refers only to Quebec. Although Czechoslovakia split into two different countries on 1 January 1993, the data displayed in this figure shows the two countries together. Data from before 1860 is only from the north of Italy.
Source: See Appendix.

The index of net marital reproduction declined in France in 1872, long before the other countries studied. Belgium followed 60 years later. England and Wales and the USA did so in 1897. New Zealand, Switzerland, and Germany followed before 1910. Between 1912 and 1930, 11 more countries joined them. Finally, the later countries followed suit from 1954 onwards: Japan, Greece, Portugal, Spain, and Ireland.

Table 2 shows the dates at which the 10% drop occurred for I_g and $I_g \times {}_{25}p_0$. The discrepancies are quite striking (column C – B). On average, there is a difference of 22 years, although in some countries this is less than 10 while in others it is more than 50. That is, there are major time differences concerning the moment when married couples decided to reduce the number of births (I_g) (the criterion followed by the PEFP) and when the index of net marital reproduction ($I_g \times {}_{25}p_0$) decreased (our own criterion of reference).

Table 2: Dates at which the 10% fall in the different indices took place

Country	A	B	C	B – A	C – B	C – A
	$_{25}q_0$	I_g	$I_g \times {}_{25}p_0$	Time differences		
Australia	*1893*	–	–	–	–	–
Austria	1887	1907	1912	20	5	25
Belgium	1866	1880	1888	14	8	22
Canada	1871	1888	1916	17	28	45
Czechoslovakia	1893	–	–	–	–	–
Denmark	1852	1889	1913	37	24	61
England and Wales	1871	1892	1897	21	5	26
Finland	1894	1912	1916	18	4	22
France	1797	1797	1827	0	30	30
Germany	1891	1891	1910	0	19	19
Greece	–	–	1958	–	–	–
Hungary	*1890*	–	1917	–	–	27
Iceland	1863	1864	1921	1	57	58
Ireland	–	1922	1974	–	52	–
Italy	1887	1915	1928	28	13	41
Japan	1928	1943	1954	15	11	26
Netherlands	1874	1898	1915	24	17	41
New Zealand	*1870*	–	1904	–	–	34
Norway	1877	1905	1915	28	10	38
Portugal	*1900*	1917	1966	17	49	66
Russian Federation	–	1921	1930	–	9	–
Spain	*1890*	1920	1970	30	50	80
Sweden	1867	1904	1913	37	9	46
Switzerland	1882	1889	1908	7	19	26
United States	*1869*	–	1897	–	–	28
Mean	1878	1898	1920	18.5	22.1	38.1
Median	1880	1904	1915	18.0	17.0	32.0

Note: Numbers in italics are reasonable estimates based on the information provided in the Appendix. The cases in which no data from sufficiently far back in time are available to accurately date when the fall began are left blank. The dates in column A were calculated from the information in Figure A-1 in the Appendix. The series published by Wrigley and Schofield (1981) shows an improvement in life expectancy from the first decade of the 19th century onwards for England and Wales, but these gains seem to have been lost between the 1820s and 1870s. Patterns in $_{25}q_0$ values indicate that there was no clear and continuous decline in mortality until the mid-19th century. We therefore decided to take 1871 as the most appropriate date for the start of the decline in mortality in England and Wales. Although Hofsten and Lundström (1976) for Sweden and Andersen (1979) for Denmark were able to establish a perceptible improvement in mortality rates from the late 18th century onwards, we preferred to set the start of the demographic transition in the second half of the 19th century, which was when the decline became permanent and continuous. The information published by James C. Riley proved very useful for our research (http://www.lifetable.de/RileyBib.htm).
Source: See Appendix.

It would be wrong to suppose that the fall in the number of births is a sign that couples desired to have fewer descendants.[11] In most countries, even several years after the decline in marital fertility (I_g) had set in, $I_g \times {}_{25}p_0$ did not fall, or even rose

[11] Various studies using micro-level data have also reached this conclusion (Knodel 1988; van Bavel 2003, 2004; Bengtsson and Dribe 2006; Reher and Sanz-Gimeno 2007; van Poppel et al. 2012; Reher and Sandström 2015; Reher et al. 2017).

(Figure 2). The index we choose to use for dating the decline in reproductive patterns may therefore lead us to draw very different assumptions regarding the causes of the demographic transition.

One of the PEFP's main conclusions was that the vast majority of European provinces (except in France) witnessed a simultaneous decline in the level of marital fertility (I_g) around the year 1900 (Coale and Watkins 1986: 37). The 'all-at-once' view has important implications for causality. As Guinnane (2011) indicates, some researchers maintain that this synchronous fertility transition serves as proof that economics has little to do with the fertility transition. Cleland and Wilson (1987: 18) maintain that "clearly the simultaneity and speed of the European transition makes it highly doubtful that any economic force could be found which was powerful enough to offer a reasonable explanation."

However, "the key underlying issue in the [adjustment or innovation] debate was the simultaneity of mortality improvement, rather than that of fertility decline" (van Poppel et al. 2012: 303). Married women in the western world reduced their fertility (I_g) as part of the adjustment process to the generalized drop in the level of mortality. If we look at the dates at which the index of net marital reproduction ($I_g \times {}_{25}p_0$) fell, we can see that the variability is much greater than that for I_g (it is almost twice as high), which means that it is very difficult to maintain the 'all-at-once' view which the PEFP defends (Table 3 and Figure 3). This is therefore another of the major disparities in the conclusions obtained when using one or other of these indices to analyze reproductive behavior.

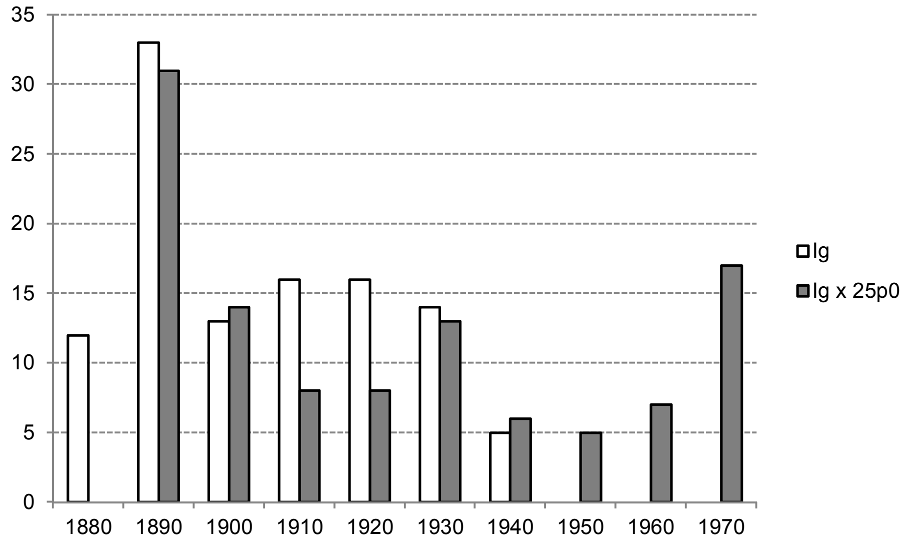
Although in most countries the index $I_g \times {}_{25}p_0$ began to drop in the early decades of the 20th century (see column C in Table 2), it is also true that in the 1960s–1970s this index began to fall more quickly in almost all cases. This might be interpreted as a feature of what has sometimes been called the second demographic transition. Behind this second transition there is a shift in norms toward individualism, which is moving Europeans away from marriage and parenthood. It has been argued that new developments from the 1970s onward can be expected to bring about sustained subreplacement fertility (Lesthaeghe and van de Kaa 1986; Van de Kaa 1987).

Table 3: Year of the 10% decline for each index (counties of England and Wales, provinces of Spain, and regions of Italy, all taken together)

	${}_{25}q_0$	I_g	$I_g \times {}_{25}p_0$
Mean	1881	1909	1927
Standard deviation	11.50	17.40	29.40
Coefficient of variation (in %)	0.61	0.91	1.53
N	109	109	109

Source: See Appendix.

Figure 3: Number of provinces according to the decade in which they experienced a 10% drop in marital fertility and the index of net marital reproduction (counties of England and Wales, provinces of Spain, and regions of Italy)



Note: The same provinces are represented in the histograms measuring I_g and I_g x ${}_{25}p_0$.
Source: See Appendix.

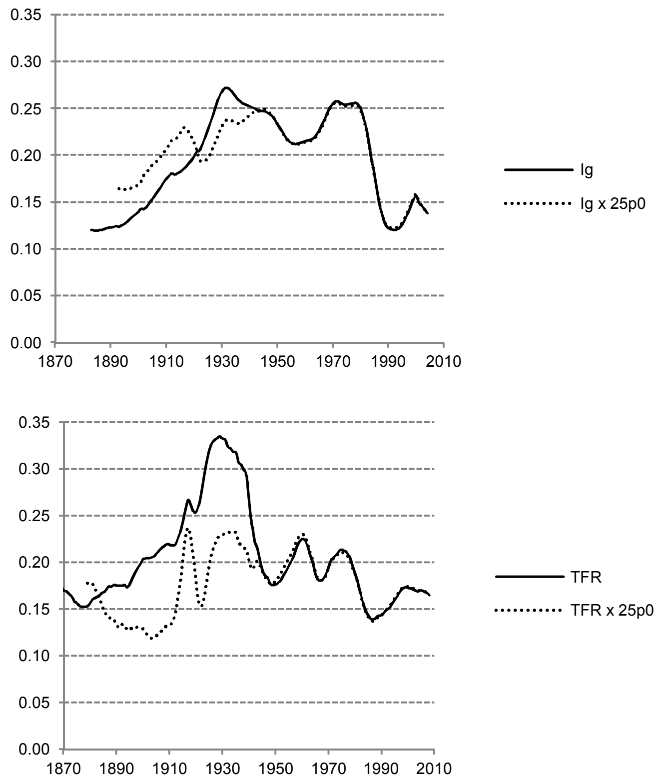
4. Description of the evolution of the index of net total reproduction (TFR × ${}_{25}p_0$): From the 'three-child pattern' to the 'two-child pattern'

In spite of the fact that the social, geographical, economic, cultural, political, and demographic circumstances of the 25 countries that we have analyzed are all different, it is striking that during the pretransitional period almost all of them had a value for the index of net total reproduction (TFR × ${}_{25}p_0$) which was around 3 (Figure 2). That is, although there were major differences in marital fertility, mortality, and nuptiality, the values for TFR × ${}_{25}p_0$ were very similar in all the countries. The differences in marital fertility between countries were balanced out by mortality and nuptiality, resulting in fairly similar values of net total reproduction. In his historical analysis of fertility in France, Wrigley (1985a: 54) found that "the tendency of changes in French nuptiality, fertility and mortality to interact in such a way as to keep the NRR very close to unity […] is of especial interest given the history of mortality in France as the nineteenth century developed." Although marital fertility, nuptiality, and mortality varied substantially during the pretransitional period, the overall changes in their combined effect were very small. According to Wrigley (1985b: 162), "a strong 'cancelling out' effect was evidently at work" between these three variables. "Changes in nuptiality and marital fertility must have been sensitive, so to speak, to each other's trends, and jointly sensitive to mortality change" (Wrigley 1985b: 165). This same equilibrium (population homeostasis) can be observed in the developments in the index of net total reproduction (TFR $\times\ {}_{25}p_0$) in the other countries analyzed before the historical decline set in (Figure 2). In the long run, mortality and total fertility must be associated, as otherwise a population would either grow explosively or become extinct.

As Figure 4 shows, in the pretransitional period and until the mid-20th century the coefficient of variation values of the TFR were much higher than those of the TFR $\times\ {}_{25}p_0$. That is, when we only consider fertility rates, the differences observed between countries are considerable. On the other hand, when we take into account the combined effect of fertility, mortality, and nuptiality (net total reproduction), the divergences are not so marked. Nonetheless, we should not minimize the difference between 'high-pressure' and 'low-pressure' demographic regimes in pretransition societies. It has been known for decades that some pretransitional societies had high fertility and high mortality, whereas others had low fertility and low mortality, even though population growth rates were low everywhere. Societies with high fertility and high mortality were often very different from societies with low fertility and low mortality, both in the social and economic context which gave rise to the demographic regimes, and in the consequences of those regimes for economic development.

In the countries for which we have data that goes back a long way, we can observe great stability in the levels of TFR $\times\ {}_{25}p_0$ and an upward trend just before the long-term decline set in (rather similar to the pattern observed for $I_g \times\ {}_{25}p_0$). Although, in general, the pretransitional net total reproduction pattern resulted in a steady figure of around three children surviving into adulthood per woman of fertile age, some exceptions can be observed. For example, Western offshoot countries clearly had higher values, generally around 4. Spain and Portugal, on the other hand, were somewhat below the European mean. However, it is in France and Ireland that the lowest pretransitional values are found (around 2).

Figure 4: Trends in values for coefficient of variation of various demographic indicators in a group of western countries



Note: N ≥ 21.
Source: See Appendix.

We can also see that in the mid-20th century, decades after the decline set in, there was a notable rise in the values of the index of net total reproduction (the ‘baby boom’). Increases in the index of net total reproduction (TFR × ${}_{25}p_0$) (around 57%) were nearly three times those of the index of net marital reproduction (I_g × ${}_{25}p_0$) (21%) because in those years a major rise in nuptiality accompanied the increase in marital fertility; that is, the so-called baby boom happened not only because married women took the step of having more children, but above all because a much greater proportion of women actually got married and because the age at marriage fell (‘marriage boom’). As Wrigley (1985a: 40) points out, “the behavior of a measure of general fertility […] is not necessarily a good guide to changes in marital fertility. Changes in the timing and prevalence of marriage may have a powerful influence on general fertility even though marital fertility changes little or not at all."

The sharp fall in values for TFR × $_{25}p_0$ that started around 1960 has still not reached bottom in some countries. Some of them have managed to halt this decline at around two children surviving until adulthood per woman. Japan and the Southern, Eastern and Central European countries (Germany, Switzerland, and Austria) are well below this level.

5. Quantification of the influence of marital fertility, mortality, and nuptiality on net total reproduction during the demographic transition

We can estimate the specific weight of I_g (marital fertility), I_m (female nuptiality), and $_{25}p_0$ (survival level) on trends in the values of net total reproduction (measured by $I_f \times {}_{25}p_0$) during the demographic transition. Our objective in this section, therefore, is to identify the relative importance of any changes in marital fertility, nuptiality, and mortality in influencing the net total reproduction in each country. First, we shall explain how we calculated this.

The Princeton indices relate to each other as follows (Coale and Watkins 1986):

$$I_f = [I_g \times I_m] + [I_h \times (1-I_m)].$$

I_h refers to the index of illegitimate births. When these only account for a tiny fraction of the total number of births, overall fertility can be represented simply as the product of marital fertility and the proportion of women who are married (I_m). We refer to overall fertility, not including illegitimate births, using the notation I'_f:

$$I'_f = [I_g \times I_m].$$

If we weight the fertility indices by the probability of survival to age 25, as we proposed in the methodological section of this article, we find that:

$$I'_f \times {}_{25}p_0 = I_g \times {}_{25}p_0 \times I_m.$$

Taking into account this relationship, column 1 of Table 4 shows the mean differences for the index $I'_f \times {}_{25}p_0$ between the values observed each year with respect to the value in the first year when the demographic transition started in each country (all values expressed in relative terms; value for initial year = 100).[12] Column 2 shows the value which variable $I'_f \times {}_{25}p_0$ would have reached if I_g had been constant with the same value as that observed in the year when the transition started. Columns 3 and 4 perform the same calculation for variables ${}_{25}p_0$ and I_m, respectively. Columns 1 to 4 show what the mean differences within countries averaged over a range of years.

Let us take the example of Austria to illustrate this approach. In Austria the demographic transition began in 1887. Between then and 1970 the average annual difference between $I'_f \times {}_{25}p_0$ and the value of $I'_f \times {}_{25}p_0$ in 1887 was –21.3% (that is, over the years 1888–1970, $I'_f \times {}_{25}p_0$ in Austria was on average 21.3% lower than it was in 1887) (see column 1). We now consider a hypothetical scenario in which the Austrian I_g remained at its 1887 level, and ${}_{25}p_0$ and I_m changed as they actually did in Austria. In such a scenario, over the years 1888–1970 the $I'_f \times {}_{25}p_0$ in Austria would have been on average 43.9% higher than it was in 1887 (because of increased survivorship and increased marriage) (see column 2). Now consider a hypothetical scenario in which Austrian mortality remained at its 1887 level, and I_g, and I_m changed as they actually did in Austria. In such a scenario, over the years 1888–1970 the $I'_f \times {}_{25}p_0$ in Austria would have been on average 39.2% lower than it was in 1887 (because of reduced fertility within marriage and changes in nuptiality) (see column 3). Finally, consider a hypothetical scenario in which Austrian nuptiality (I_m) remained at its 1887 level, and the I_g and ${}_{25}p_0$ changed as they actually did in Austria. In such a scenario, over the years 1888–1970 the $I'_f \times {}_{25}p_0$ in Austria would have been on average 24.6% lower than it was in 1887 (because of reduced fertility within marriage and changes in mortality) (see column 4).

Columns 5, 6, and 7 show the estimation of the incidence of the different variables on the long-term development of $I'_f \times {}_{25}p_0$ and are calculated by subtracting the values in columns 2, 3, and 4 from those in column 1. The difference between the value which would have occurred if one of the variables (I_g, ${}_{25}p_0$, or I_m) that influenced the development of $I'_f \times {}_{25}p_0$ had remained constant (columns 2, 3, and 4) and the value of the mean differences within countries observed for $I'_f \times {}_{25}p_0$ (column 1) allows us to obtain a reasonable estimate of the specific weight of each of these variables (I_g, ${}_{25}p_0$, and I_m) over the development of $I'_f \times {}_{25}p_0$ during the demographic transition.

What columns 5, 6, and 7 tell us is that it was the decline in marital fertility (I_g) that most conditioned the value of net total reproduction ($I'_f \times {}_{25}p_0$). This would have increased on average by 54.9% if the values of I_g for the first year of the transition had been maintained. If survival rates (${}_{25}p_0$) had remained constant, the value of $I'_f \times {}_{25}p_0$

[12] The transition was taken to start in the year when the value of ${}_{25}q_0$ fell by 10% (as long as the value of ${}_{25}q_0$ did not subsequently return to the level of the previous plateau). The end of the transition was set as 1970 for all countries, since from that year onwards some countries saw a steep rise in the number of births outside marriage, and because all the countries had already attained very low levels of mortality. Figure A-2 in the Appendix shows the developments in both $I_f \times {}_{25}p_0$ and $I'_f \times {}_{25}p_0$.

would have fallen by 18.1%. Finally, the marriage index was the variable with the most modest influence on the net total reproduction. If the value of I_m in the first year of the transition had been maintained it would only have reduced the values of $I'_f \times {}_{25}p_0$ by 6.5%. If in the pretransitional stage the control over total fertility was basically exercised by marriage, once the transition had begun, control over fertility came to be exerted within marriage (Wrigley 1985b: 164).

Once again, analysis of the data from each country reveals a considerable degree of heterogeneity in the demographic patterns adopted in the Western world over the demographic transition period. While in Ireland, Spain, New Zealand, Italy, and Portugal the influence of the drop in marital fertility (I_g) was moderate, in Denmark, Germany, and particularly France and Belgium, it was very high. The increase in survival (${}_{25}p_0$) had only a modest effect in New Zealand, England and Wales, the USA, Norway, and Finland, while in France, the Netherlands, Italy, Spain, Belgium, and, above all, Ireland, it was much more intense. Ireland is the only country where gains in survival (${}_{25}p_0$) had an effect on $I'_f \times {}_{25}p_0$ greater than that of the fall in marital fertility (I_g).

As for marriage, although we have already pointed out that its effect on $I'_f \times {}_{25}p_0$ was much less pronounced than that of the other two variables, there are still noteworthy differences between countries. Whereas in France, Denmark, Canada, and especially Belgium the nuptiality values considerably softened the drop in $I'_f \times {}_{25}p_0$, in Spain they exacerbated this fall considerably. In most countries I_m had practically no effect (Austria, Finland, and Italy), or only a very minor one.

The figures for each country displayed in the different columns in Table 4 are the average values observed for the whole period of the demographic transition. The use of mean values has the great advantage that one number summarizes the changes in a given variable over a specific period, although these mean values necessarily conceal the variability that occurred in that period. To compensate for this limitation, Figure A-3 in the Appendix shows the annual development of the values in columns 5, 6, and 7 in Table 4. This enables us to see the different impact of variables I_g, ${}_{25}p_0$, and I_m on $I'_f \times {}_{25}p_0$ over each of the years of the demographic transition in each country.

Table 4: Estimate of the influence of variables I_g, ${}_{25}p_0$, and I_m on the evolution of the index of net total reproduction ($I'_f \times {}_{25}p_0$) over the demographic transition period (in percentage)

	Demographic transition			Mean difference	New value of mean difference of $I'_f \times {}_{25}p_0$ when base value of the following variable is kept constant			Estimate of incidence of different variables on evolution of $I'_f \times {}_{25}p_0$		
				$I'_f \times {}_{25}p_0$	I_g	${}_{25}p_0$	I_m	I_g	${}_{25}p_0$	I_m
Country	Start	End	Length	(1)	(2)	(3)	(4)	(5)=(2)–(1)	(6)=(3)–(1)	(7)=(4)–(1)
Austria	1887	1970	83	–21.3	43.9	–39.2	–24.6	65.3	–17.9	–3.3
Belgium	1866	1970	104	–13.2	92.8	–34.7	–35.9	106.1	–21.5	–22.6
Canada	1871	1970	99	–2.0	58.9	–20.9	–18.6	60.8	–18.9	–16.7
Denmark	1852	1970	118	–3.0	63.7	–23.8	–19.1	66.7	–20.9	–16.1
England and Wales	1871	1970	99	–25.2	39.8	–39.6	–29.1	65.0	–14.4	–3.9
Finland	1894	1970	76	–18.9	21.9	–31.6	–17.3	40.7	–12.7	1.5
France	1797	1970	173	–10.9	89.5	–45.0	–23.4	100.5	–34.0	–12.5
Germany	1891	1970	79	–23.4	45.0	–39.4	–29.0	68.4	–16.0	–5.7
Ireland	1873	1970	97	28.4	44.4	–13.7	33.2	16.0	–42.1	4.7
Italy	1887	1970	83	–1.6	35.0	–25.2	0.4	36.6	–23.6	2.0
Netherlands	1874	1970	96	2.0	59.6	–25.5	–8.0	57.6	–27.5	–10.0
New Zealand	1893	1970	77	–13.4	21.4	–20.8	–21.4	34.8	–7.4	–8.0
Norway	1877	1970	93	–10.8	41.2	–23.1	–21.8	52.0	–12.3	–11.0
Portugal	1900	1970	70	–0.6	36.2	–18.7	–7.9	36.8	–18.1	–7.2
Spain	1904	1970	66	–3.8	23.2	–26.7	6.4	26.9	–22.9	10.2
Sweden	1867	1970	103	–10.4	50.7	–28.6	–18.6	61.2	–18.1	–8.2
Switzerland	1882	1970	88	–13.1	36.3	–28.9	–18.8	49.4	–15.8	–5.7
USA	1882	1970	88	–20.7	31.6	–32.8	–26.4	52.3	–12.1	–5.7
Mean *				–9.0	46.4	–28.8	–15.6	55.4	–19.8	–6.6
Median				–10.9	42.5	–27.6	–19.0	54.9	–18.1	–6.5

* The mean values may be problematic, as they are obtained using unweighted values from all countries (with populations of very different sizes).
Note: See explanations in text. The years of the demographic transition for Ireland, New Zealand, and the United States were set as above because no earlier information was available concerning the Princeton indices.
Source: See Appendix.

6. Nonhomogeneous effect of mortality on net total reproduction during the demographic transition

Considerable confusion persists among demographers regarding the role of reductions in mortality as a driver of fertility transition. One of the PEFP's main conclusions was that we cannot deduce from the aggregate data gathered for the provinces in Europe that the declines in mortality led to the subsequent fall in fertility (van de Walle 1986: 233). Many other researchers have reached the same conclusion (Watkins 1986: 436; Knodel 1974: 167–185; Lesthaeghe 1977: 171–176; Teitelbaum 1984; Haines 1998). Recent quantitative and empirical evidence (Doepke 2005; Fernández-Villaverde 2001; Murphy 2009) has also shed light on the negligible role of declining mortality in accounting for falling fertility. Nonetheless, many authors have stressed the special role played by mortality in the fertility transition (Mason 1997; Galloway, Lee, and Hammel 1998; Cleland 2001; Reher and Sanz-Gimeno 2007; Dyson 2010; van Poppel et al. 2012; Schellekens and van Poppel 2012; Sánchez-Barricarte 2017a). Recently, Ángeles (2010), Herzer, Strulik, and Vollmer (2012), and Murtin (2013), using panel data analyses covering long time periods, have shown that mortality rates are a statistically significant predictor of total fertility rates.

Reher et al. (2017) address the role of mortality in reproductive decision-making during the demographic transition using microdata on individual reproductive histories from Spain, Sweden, and the Netherlands. They found that couples were continuously regulating their fertility to achieve reproductive goals, thus providing an important contribution to the literature on the role of mortality in reproductive behavior. They show that couples that lost a child had a higher probability of having another child.

Van Bavel and Kok (2010), using three elaborate family reconstructions covering two provinces of the Netherlands in the period 1825–1885, find that pretransition couples indeed spaced their births during roughly the first ten years of marriage. Bengtsson and Dribe (2006), using survival analysis on a longitudinal dataset at the individual level combined with food prices, also find that families in a rural population in Sweden controlled the timing of childbirth before the fertility transition. Van Bavel (2004), using three birth cohorts that lived in 19^{th} century Leuven (Belgium), finds that birth intervals were not merely a function of natural fertility differences but that families' strategic spacing behavior also played a role. He finds that the death of the last child more or less doubles the hazard rate of conception.

In what follows we will analyze the effect of mortality on net reproduction (total and marital) over the different stages within the demographic transition using aggregate data. Other authors have put forward various mechanisms to explain how mortality might have affected fertility in different ways (Strulik and Weisdorf 2014; Cervellati and Sunde 2015; Sánchez-Barricarte 2017a, 2017b), although only Luis Ángeles (2015) analyzes the effect of mortality rates on net total reproduction.

Figures 5 and 6 show the changes in the correlation between mortality (${}_{25}q_0$) and net marital and total reproduction ($I_g \times {}_{25}p_0$ and $I_f \times {}_{25}p_0$, respectively) at the provincial level in seven European countries.[13] We can see that the effect of mortality on net reproduction was not homogeneous throughout the different phases of the transition. The two figures show that in the pretransitional stage and in the first decades after the onset of the transition the relationship was clearly negative: When mortality was high, women needed to use all their fertile years to have children. The latent demand for children surviving into adulthood was high, and therefore those provinces with the highest mortality were also those with the lowest net reproduction.

As the transition progressed and mortality rates underwent a certain improvement, the effect of mortality on net reproduction became less negative, or even zero. As Ángeles (2015: 13) states, "the effect may even become positive if some additional mechanism is in place, such as hoarding or the quantity – quality tradeoff, which would make net fertility directly a function of mortality rates." Indeed, in Figures 5 and 6 we can see that in the last decades of the fertility transition the correlations between the two variables have high positive signs.

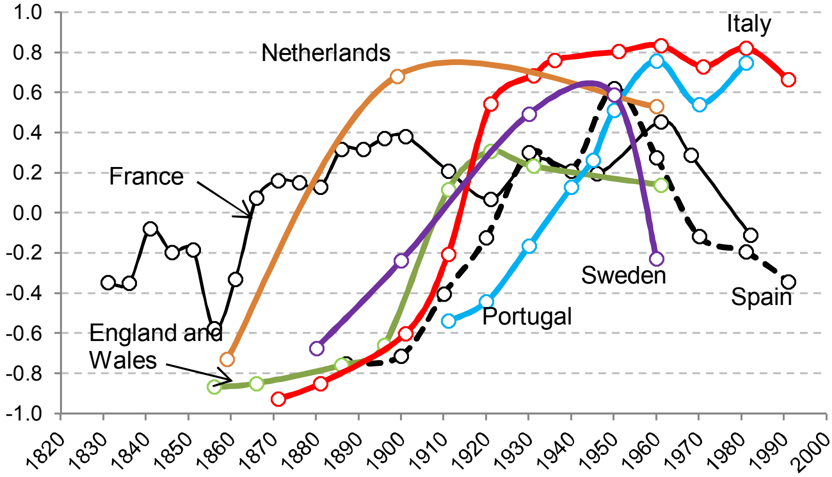
There is a strong positive relationship between the moment when these correlations changed sign (from negative to positive) and the point at which the drop in mortality rates began in the different countries in question (Table 2): The countries in which the drop in mortality began earlier were also those that first experienced the change in the sign of the correlations set out in Figures 5 and 6 (regarding both net marital and total reproduction).

The time frame over which the relationship changes from negative to positive varies enormously, especially when $I_g \times {}_{25}p_0$ is plotted (Figure 5) rather than when $I_f \times {}_{25}p_0$ is shown (Figure 6). This is because the values of I_g have greater variability than those of I_f. Over a large part of the demographic transition the nuptial system was very flexible in Western Europe. Age at marriage and the proportion of people who remained single varied greatly. Nuptiality certainly played an important role in regulating the total number of births. As Wrigley (1985a: 46) states, "the most distinctive regulatory mechanism among west European populations of the early modern period was marriage." Mortality and nuptiality therefore acted together to balance out the major differences between provinces in marital fertility rates, and therefore to produce values of $I_f \times {}_{25}p_0$ that were much more similar.[14]

[13] The Appendix provides the sources of the provincial data for the seven countries where we obtained information about mortality levels (${}_{25}q_0$) and fertility levels (I_f, I_g) within provinces.

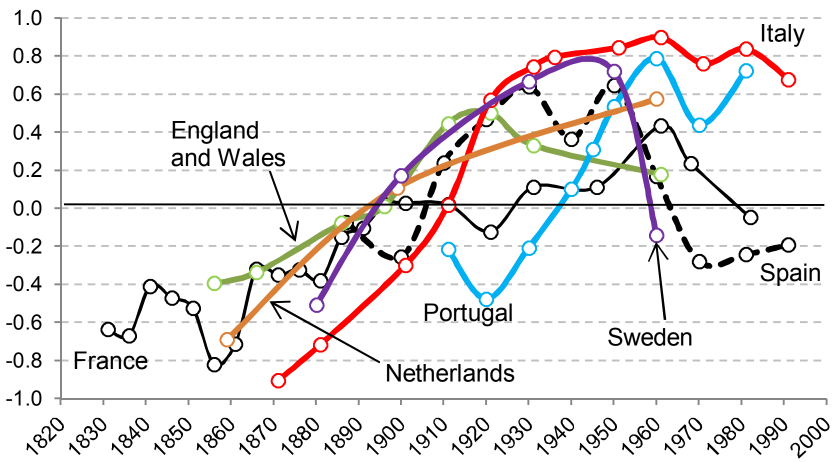
[14] "Where mortality was unusually high or marital fertility unusually low, nuptiality tended to be high, and vice versa, resulting in intrinsic growth rates close to zero (or at least in close adjustment to local economic circumstances" (Wrigley 1985a: 47).

Figure 5: Correlation coefficients between the index of net marital reproduction (I_g x $_{25}p_0$) and mortality ($_{25}q_0$) (provincial level)



Source: See Appendix.

Figure 6: Correlation coefficients between the index of net total reproduction (I_f x $_{25}p_0$) and mortality ($_{25}q_0$) (provincial level)



Source: See Appendix.

7. Conclusions

Our analysis of net reproduction has provided a view of the demographic transition that diverges considerably from that presented in traditional studies based on trends in the fertility rate alone (marital or total). Regardless of whether the ultimate aim is to compare marital fertility patterns in different countries or to undertake a detailed study of a single country over a long time period during which mortality rates have undergone major changes, it is essential to use an index of net marital reproduction. There is little point in analyzing fertility trends if we leave out the mortality scenario that forms the background to these tendencies.

The net total reproduction indicators that we have used in this study have enabled us to show that the differences in the pretransitional era were not as great as those which appear when we look only at fertility: Both nuptiality and mortality play a part in tempering these contrasts.

Our analysis of net marital reproduction has enabled us to challenge the idea, widely accepted in the ambit of the PEFP, that the fertility transition happened at almost the same time across all European provinces. On the contrary, we found major diversity concerning the time point at which couples began to reduce the number of children who actually survived to become adults.

We were also able to quantify the different roles played by marital fertility, mortality, and nuptiality in net total reproduction trends. We found that nuptiality was the variable that had the least impact.

Lastly, we also show the existence of a nonhomogeneous effect of mortality on net reproduction. On the basis of provincial data from seven European countries, we found that mortality had a changing effect over the years of the demographic transition: negative during the pre- and peritransitional phases, and positive during the final stage of the transition.

Some of our conclusions concur with those of studies based on micro-level data. The originality of our research therefore lies in the fact that we were able to use aggregated data from large geographical areas over long historical periods to corroborate the results of small-scale studies based on family reconstruction. Whereas during the past decade micro-level data has increasingly been used to unravel the complex links between the long-term evolution of fertility and mortality, in this paper we provide important macro-level indicators.

References

Alter, G. (1988). *Family and the female life course: The women of Verviers, Belgium, 1849–1880*. Madison: The University of Wisconsin Press.

Andersen, O. (1979). The development of Danish mortality, 1735–1850. *Scandinavian Population Studies* 5: 9–21.

Anderson, M., Ó Gráda, C., Wrigley, E., and Woods, R. (2001). Las Islas Británicas [The British isles]. In: Bardet, J.P. and Dupâquier, J. (eds.). *Historia de las poblaciones de Europa: II. La revolución demográfica, 1750–1914 [History of the populations of Europe: II. The demographic revolution, 1750–1914]*. Madrid: Síntesis: 291–308.

Andreev, E., Darskij, L., and Kharkova, T. (1992). L'histoire de la population de l'URSS, 1920–1959. *Annales de Demographie Historique* 1992(1): 61–150.

Ángeles, L. (2010). Demographic transitions: Analyzing the effects of mortality on fertility. *Journal of Population Economics* 23(1): 99–120. doi:10.1007/s00148-009-0255-6.

Ángeles, L. (2015). *Tracking how mortality affects fertility along the demographic transition*. Paper presented at the 11th European Historical Economics Society Conference 2015, Pisa, Italy, September 4–5, 2015.

Bengtsson, T. and Dribe, M. (2006). Deliberate control in a natural fertility population, Southern Sweden, 1766–1864. *Demography* 43(4): 727–746. doi:10.1353/dem.2006.0030.

Blanes, A. (2007). La mortalidad en la España del siglo XX: Análisis demográfico y territorial [Child mortality in Spain in the 20th century: Demographic and territorial analysis] [PhD thesis]. Barcelona: Universidad Autónoma de Barcelona, Departamento de Geografía.

Blayo, Y. (1975). La mortalité en France de 1740 à 1829 [The mortality in France from 1740 to 1829]. *Population* 30(1): 123–142. doi:10.2307/1530647.

Blum, A. and Troitskaja, I. (1996). La mortalité en Russie aux XVIIIe et XIXe siècles: Estimations locales à partir des Revizii [Mortality in Russia in the 18th and 19th centuries: The local estimates of Revizii]. *Population* 51: 303–328. doi:10.3917/popu.p1996.51n2.0328.

Bogue, D. (1993). Empirical interrelationships among standard fertility measures. In: Bogue, D., Arriaga, E., Anderton, D., and Rumsey, G. (eds.). *Readings in population research methodology: Fertility research*. Chicago: Social Development Center: 11–53.

Bonneuil, N. (1997). *Transformation of the French demographic landscape, 1806–1906*. Oxford: Clarendon Press. http://table_mortalite_bonneuil.site.ined.fr/en/presentation/.

Bourbeau, R., Légaré, J., and Émond, V. (1997). New birth cohort life tables for Canada and Quebec, 1801–1991. Ottawa: Statistics Canada, Demography Division. http://dsp-psd.pwgsc.gc.ca/Collection/Statcan/91F0015M/91F0015MIE1997003.pdf.

Boyle, P. and Ó Gráda, C. (1986). Fertility trends, excess mortality, and the Great Irish Famine. *Demography* 23(4): 543–562.

Brunborg, H. (1976). The inverse projection method applied to Norway, 1735–1974 [unpublished manuscript]. Oslo: Statistics Norway.

Bryant, J. (2007). Theories of fertility decline and the evidence from development indicators. *Population and Development Review* 33(1): 101–127. doi:10.1111/j.1728-4457.2007.00160.x.

Calot, G., Confesson, A., Sardon, J.P., Baranzini, E., Cotter, S., and Wanner, P. (1998). *Two centuries of Swiss demographic history: Graphic album of the 1860–2050 period*. Neuenburg: Swiss Federal Statistical Office.

Campbell, H. (1973). Net reproduction-rate in England and Wales. *Lancet* 302(7838): 1143. doi:10.1016/S0140-6736(73)90951-3.

Carrilho, M.J. (1980). Tábuas abreviadas de mortalidade, 1941–1975 [Abridged life tables, 1941–1975]. Lisbon: Imprensa Nacional – Casa da Moeda.

Casterline, J. (2001). The pace of fertility transition: National patterns in the second half of the twentieth century. *Population and Development Review* 27(Supplement): 17–52.

Centro de Estudos Demográficos (1976). Tábuas abreviadas de mortalidade distritais e regionais, 1959–1962 e 1969–1972 [Abridged life tables by districts and regions, 1959–1962 and 1969–1972]. Lisbon: Instituto Nacional de Estatística.

Cervellati, M. and Sunde, U. (2015). The effect of life expectancy on education and population dynamics. *Empirical Economics* 48(4): 1445–1478. doi:10.1007/s00181-014-0830-x.

Chesnais, J.C. (1992). *The demographic transition: Stages, patterns, and economic implications*. New York: Oxford University Press.

Chesnais, J.C. (1998). Below-replacement fertility in the European Union (EU–15): Facts and policies, 1960–1997. *Review of Population and Social Policy* 7: 83–101.

Cleland, J. (2001). The effects of improved survival on fertility: A reassessment. *Population and Development Review* 27 (Supplement): 60–92.

Cleland, J. and Wilson, C. (1987). Demand theories of the fertility transition: An iconoclastic view. *Population Studies* 41(1): 5–30. doi:10.1080/0032472031000142516.

Coale, A. and Demeny, P. (1983). *Regional model life tables and stable populations*. New York: Academic Press. doi:10.1016/B978-0-12-177080-8.50007-X.

Coale, A. and Watkins, S. (1986). *The decline of fertility in Europe*. Princeton: Princeton University Press. http://opr.princeton.edu/archive/pefp/.

Cónin, C., Marques, A., and Pinto, J. (1988). Tábuas abreviadas de mortalidade, distritos e regiões autónomas, 1979–1982 [Abridged life tables, districts and autonomous regions, 1979–1982]. Lisbon: Centro de Estudos Demográficos, Instituto Nacional de Estatística.

Cummins, N. (2009). Why did fertility decline? An analysis of the individual level economic correlates of the nineteenth century fertility transition in England and France [PhD thesis]. London: London School of Economics, Department of Economic History.

Davenport, R. (2016). Urban family reconstitution – a worked example. *Local Population Studies* 96: 28–49. doi:10.2307/2732014.

Davis, K. (1963). The theory of change and response in modern demographic history. *Population Index* 29(4): 345–366.

Doepke, M. (2005). Child mortality and fertility decline: Does the Barro–Becker model fit the facts? *Journal of Population Economics* 18(2): 337–366. doi:10.1007/s00148-004-0208-z.

Dopico, F. (1987). Regional mortality tables for Spain in the 1860s. *Historical Methods* 20(4): 173–179.

Dopico, F. and Reher, D. (1998). *El declive de la mortalidad en España, 1860–1930* [*The decline of mortality in Spain, 1860–1930*]. Huesca: Asociación de Demografía Histórica.

Dyson, T. (2010). *Population and development: The demographic transition*. London: Zed Books.

Dyson, T. and Murphy, M. (1985). The onset of fertility transition. *Population and Development Review* 11(3): 399–440. doi:10.2307/1973246.

Fernández-Villaverde, J. (2001). Was Malthus right? Economic growth and population dynamics. Pennsylvania: University of Pennsylvania (PIER working paper 01-046). doi:10.2139/ssrn.293800.

Galloway, P. (1994). A reconstruction of the population of North Italy from 1650 to 1881 using annual inverse projection with comparison to England, France, and Sweden. *European Journal of Population* 10(3): 223–274.

Galloway, P., Lee, R., and Hammel, E. (1998). Infant mortality and the fertility transition. In: Montgomery, M. and Cohen, B. (eds.). *From death to birth: Mortality decline and reproductive change.* Washington, D.C.: National Academy Press: 182–226.

Galor, O. (2005a). From stagnation to growth: Unified growth theory. In: Aghion, P. and Durlauf, S.N. (eds.). *Handbook of economic growth.* Amsterdam: Elsevier: 171–293. doi:10.1016/S1574-0684(05)01004-X.

Galor, O. (2005b). The demographic transition and the emergence of sustained economic growth. *Journal of the European Economic Association* 3(2–3): 494–504. doi:10.1162/jeea.2005.3.2-3.494.

Galor, O. (2012). The demographic transition: Causes and consequences. *Cliometrica* 6(1): 1–28. doi:10.1007/s11698-011-0062-7.

Glass, D.V. (1940). Population policies and movements in Europe. *Economic Journal* 50(200): 488–490. doi:10.2307/2226211.

Glass, D.V. (1945). Reproduction rates of France and Spain: A survey of recent literature. *Eugenics Review* 37(2): 61–64.

Guinnane, T. (2011). The historical fertility transition: A guide for economists. *Journal of Economic Literature* 49(3): 589–614. doi:10.1257/jel.49.3.589.

Hacker, D. (2003). Rethinking the ‘early’ decline of marital fertility in the United States. *Demography* 40(4): 605–620.

Hacker, J. (2010). Decennial life tables for the white population of the United States, 1790–1900. *Historical Methods* 43(2): 45–79.

Haines, M. (1998). The relationship between infant and child mortality and fertility: Some historical and contemporary evidence for the United States. In: Montgomery, M. and Cohen, B. (eds.). *From deaths to births: Mortality decline and reproductive change*. Washington, D.C.: National Academy Press: 227–253.

Haines, M.R. and Steckel, R.H. (2000). *The population history of North America*. Cambridge: Cambridge University Press.

Henripin, J. (1972). *Trends and factors of fertility in Canada*. Ottawa: Statistics Canada. http://publications.gc.ca/collections/collection_2017/statcan/CS99-541-1972-eng.pdf.

Henry, L. (1961). Some data on natural fertility. *Eugenics Quarterly* 8(2): 81–92. doi:10.1080/19485565.1961.9987465.

Herzer, D., Strulik, H., and Vollmer, S. (2012). The long-run determinants of fertility: One century of demographic change, 1900–1999. *Journal of Economic Growth* 17(4): 357–385. doi:10.1007/s10887-012-9085-6.

Hinde, A. (1998). *Demographic methods*. London: Arnold.

Hofsten, E. and Lundström, H. (1976). *Swedish population history: Main trends from 1750 to 1970*. Stockholm: Liber.

Hogben, L. (1938). *Political arithmetic: A symposium of population studies*. New York: Routledge.

Hungarian Central Statistical Office (1992). Time series of historical statistics, 1867–1992. Budapest: Hungarian Central Statistical Office.

Hyrenius, H. (1951). Reproduction and replacement. *Population Studies* 4(4): 421–431. doi:10.1080/00324728.1951.10416787.

Imhof, A. (1990). *Lebenserwartungen in Deutschland vom 17. bis 19. Jahrhundert* [*Life expectancies in Germany from the 17th to the 19th century*]. Weinheim: Acta Humaniora.

Johansen, H. (2002). *Danish population history, 1600–1939*. Odense: University Press of Southern Denmark.

Johansen, H. and Oeppen, J. (2001). Danish population estimates, 1665–1840. Odense: Danish Center for Demograpic Research (Research report 21).

Kirk, D. (1996). Demographic transition theory. *Population Studies* 50(3): 361–387. doi:10.1080/0032472031000149536.

Knodel, J. (1974). *The decline of fertility in Germany, 1871–1939*. Princeton: Princeton University Press.

Knodel, J. (1978). European populations in the past: Family-level relations. In: Preston, S.H. (ed.). *The effects of infant and child mortality on fertility*. New York: Academic Press: 21–45.

Knodel, J. (1988). *Demographic behavior in the past: A study of fourteen German village populations in the eighteenth and nineteenth centuries*. Cambridge: Cambridge University Press. doi:10.1017/CBO9780511523403.

Knodel, J. and Van de Walle, E. (1967). Breast feeding, fertility, and infant mortality: An analysis of some early German data. *Population Studies* 21(2): 109–131. doi:10.2307/2172715.

Kollega, T.I. (1996). *Magyarország a XX században* [*Hungary in the 20st century*]. Szekszárd: Babits.

Kuczynski, R. (1942). *The new population statistics*. Cambridge: Cambridge University Press.

Lesthaeghe, R. (1977). *The decline of Belgian fertility, 1800–1970*. Princeton: Princeton University Press.

Lesthaeghe, R. and Van de Kaa, D. (1986). Twee demografische transities? [Two demographic transitions?] In: Lesthaeghe, R. and Van de Kaa, D. (eds.). *Bevolking-groei en krimp, mens en maatschappij [Population growth and shrinkage, people, and society]*. Deventer: Van Loghum Slaterus: 9–24.

Livi-Bacci, M. (1968). Fertility and nuptiality changes in Spain from the late 18th to the early 20th century. *Population Studies* 22: 83–102 and 211–234. doi:10.1080/00324728.1968.10405536.

Lotka, A. (1936). Modern trends in the birth rate. *Annals of the American Academy of Political and Social Science* 188(1): 1–13. doi:10.1177/000271623618800102.

Lutz, W. (1987). *Finnish fertility since 1722: Lessons from an extended decline*. Helsinki: The Population Research Institute.

Maddison, A. (2009). Historical statistics of the world economy (1–2008 AD) [electronic resource]. Groningen: University of Groningen. www.ggdc.net/maddison/Historical_Statistics/horizontal-file_02-2010.xls.

Mason, K. (1997). Explaining fertility transitions. *Demography* 34(4): 443–454. doi:10.2307/3038299.

Matthiessen, P.C. and McCann, J.C. (1978). The role of mortality in the European fertility transition: Aggregate-level relations. In: Preston, S.H. (ed.). *The effects of infant and child mortality on fertility*. New York: Academic Press: 47–68.

Matthiessen, P.C. (1985). *The limitation of family size in Denmark I–II*. Copenhagen: Royal Danish Academy of Science and Letters.

Mitchell, B.R. (2007a). *International historical statistics: Africa, Asia, and Oceania, 1750–2005.* Houndmills: Palgrave MacMillan.

Mitchell, B.R. (2007b). *International historical statistics: The Americas, 1750–2005.* Houndmills: Palgrave MacMillan.

Mitchell, B.R. (2007c). *International historical statistics: Europe, 1750–2005.* Houndmills: Palgrave MacMillan.

Murphy, T. (2009). Old habits die hard (sometimes): What can département heterogeneity tell us about the French fertility decline? Milano: Bocconi University (IGIER working paper 364).

Murtin, F. (2013). The long-term determinants of the demographic transition, 1870–2000. *Review of Economics and Statistics* 95(2): 617–631. doi:10.1162/REST_a_00302.

Nazareth, M. (1977). Tábuas abreviadas de mortalidade globais e regionais: 1929–1932, 1939–1942 e 1949–1952 [Global and regional abridged life tables: 1929–1932, 1939–1942, and 1949–1952]. Lisbon: Centro de Estudos Demográficos, Instituto Nacional de Estatística.

Needleman, L. (1986). Canadian fertility trends in perspective. *Journal of Biosocial Science* 18(1): 43–56. doi:10.1017/S0021932000006489.

Newell, C. (1988). *Methods and models in demography*. London: Belhaven.

Notestein, F.W. (1945). Population: The long view. In: Schultz, T.W. (ed.). *Food for the world*. Chicago: University of Chicago Press: 36–57.

Ó Gráda, C. (1979). The population of Ireland, 1700–1900: A survey. *Annales de Démographie Historique* 1979(1): 281–299. doi:10.3406/adh.1979.1425.

Palloni, A. and Rafalimanana, H. (1999). The effects of infant mortality on fertility revisited: New evidence from Latin America. *Demography* 36(1): 41–58. doi:10.2307/2648133.

Pool, I. (1982). Is New Zealand a healthy country? The centenary of Dr. Alfred Newman's affirmation 'that it is yet the healthiest on the face of the globe.' *New Zealand Population Review* 8(2): 2–27.

Pool, I. (1985). Mortality trends and differentials. New York: United Nations: 209–242 (Country Monograph Series 12).

Pool, I. (1993). New Zealand's two health transitions: A comparative analysis. In: International Union for the Scientific Study of Population (ed.). *International Population Conference / Congres International de la Population, Montreal 1993, 24th August–1st September, Volume 1*. Liege: IUSSP: 419–427.

Pool, I. and Cheung, J. (2003). A cohort history of mortality in New Zealand. *New Zealand Population Review* 29(2): 107–138.

Pool, I. and Cheung, J. (2005). Why were New Zealand levels of life expectancy so high at the dawn of the twentieth century? *Genus* 61(2): 9–33.

Pouyez, C. and Lavoie, Y. (1983). *Les Saguenayens: Introduction à l'histoire des populations du Saguenay XVIe–XXe siècles [Les Saguenayens: Introduction to the history of the populations of Saguenay, 16th–20th century]*. Sillery: Presses de l'Université du Québec.

Quetelet, A. (1851). Nouvelles tables de mortalité pour la Belgique [New life tables for Belgium]. *Bulletin de la Commission Centrale de Statistique* 4: 1–22.

Rédei J. (1960). *A születések ás halálozások alakulása a XIX. és XX. században Ewrópában és Magyarországon [Births and deaths in Europe and Hungary in the 19th and 20th centuries]*. Budapest: Közgazdasági és Jogi Kiadó.

Reher, D. and Sandström, G. (2015). Dimensions of rational decision-making during the demographic transition: Aranjuez (Spain) revisited. *Historical Life Course Studies* 2: 20–36.

Reher, D. and Sanz-Gimeno, A. (2007). Rethinking historical reproductive change: Insights from longitudinal data for a Spanish town. *Population and Development Review* 33(4): 703–727. doi:10.2307/25487619.

Reher, D., Sandström, G., Sanz-Gimeno, A., and Van Poppel, F. (2017). Agency in fertility decisions in Western Europe during the demographic transition: A comparative perspective. *Demography* 54(1): 3–22. doi:10.1007/s13524-016-0536-0.

Rodrigues Veiga, T., Guardado Moreira, M., and Fernandes, A. (2004). Social changes and better health conditions of the Portuguese population, 1974–2000. *Hygiea Internationalis* 4(1): 255–276.

Rothenbacher, F. (2002). *The European population, 1850–1945*. New York: Palgrave MacMillan. doi:10.1007/9781-137-43366-4.

Sánchez-Barricarte, J.J. (2017a). Mortality–fertility synergies during the demographic transition in the developed world. *Population Studies* 71(2): 155–170. doi:10.1080/00324728.2017.1294701.

Sánchez-Barricarte, J.J. (2017b). The long-term determinants of marital fertility in the developed world (19^{th} and 20^{th} centuries): The role of welfare policies. *Demographic Research* 36(42): 1255–1298. doi:10.4054/DemRes.2017.36.42.

Sardon, J.-P. (1991). Generation replacement in Europe since 1900. *Population: An English Selection* 3(1991): 15–32.

Sardon, J.-P. (1996). Coale's indices, comparative indices, mean generation, total fertility rate, and components. *Population: An English Selection* 8(1996): 252–257.

Schellekens, J. and Van Poppel, F. (2012). Marital fertility decline in the Netherlands: Child mortality, real wages, and unemployment, 1860–1939. *Demography* 49(3): 965–988. doi:10.1007/s13524-012-0112-1.

Siampos, G. (1989). *Mortality decline and longevity in Greece*. Athens: Epiloyi.

Smith, D. (1972). The demographic history of colonial New England. *Journal of Economic History* 32(1): 165–183. doi:10.1017/S0022050700075458.

Srb, V. (1962). Population development and population policy in Czechoslovakia. *Population Studies* 16(2): 147–159.

Strulik, H. and Weisdorf, H. (2014). How child costs and survival shaped the Industrial Revolution and the demographic transition. *Macroeconomic Dynamics* 18(1): 114–144. doi:10.1017/S1365100512000302.

Taeuber, I. (1958). *The population of Japan*. Princeton: Princeton University Press.

Teitelbaum, M. (1984). *The British fertility decline: Demographic transition in the crucible of the Industrial Revolution.* Princeton: Princeton University Press. doi:10.1515/9781400857159.

Turpeinen, O. and Kannisto, V. (1997). Abridged life tables for Finland, 1751–1880. Helsinki: Statistics Finland.

United Nations, Department of Economic and Social Affairs, Population Division (2015). World population prospects: The 2015 revision, DVD edition. New York: United Nations. https://esa.un.org/unpd/wpp/Download/Standard/Fertility/.

US Department of Health, Education, and Welfare (1950). *Vital statistics of the United States.* Washington, D.C.: US Printing Office.

Vallin, J. (1991). Mortality in Europe from 1720 to 1914: Long-term trends and changes in patterns by age and sex. In: Schofield, R., Reher, D., and Bideau, A. (eds.). *The decline of mortality in Europe*. Oxford: Clarendon Press: 38–67.

Van Bavel, J. (2003). Birth spacing as a family strategy: Evidence from 19th century Leuven, Belgium. *History of the Family* 8(4): 585–604. doi:10.1016/j.hisfam.2003.03.001.

Van Bavel, J. (2004). Deliberate birth spacing before the fertility transition in Europe: Evidence from nineteenth century Belgium. *Population Studies* 58(1): 95–107. doi:10.1080/0032472032000167706.

Van Bavel, J. and Kok, J. (2010). A mixed effects model of birth spacing for pre-transition populations. Evidence of deliberate fertility control from nineteenth century Netherlands. *History of the Family* 15(2): 125–138. doi:10.1016/j.hisfam.2009.12.004.

Van de Kaa, D. (1987). Europe's second demographic transition. *Population Bulletin* 42(1): 1–59.

Van de Walle, E. (1974). *The female population of France in the nineteenth century.* Princeton: Princeton University Press.

Van de Walle, F. (1986). Infant mortality and the European demographic transition. In: Coale, A. and Watkins, S. (eds.). *The decline of fertility in Europe*. Princeton: Princeton University Press: 201–233.

Van Poppel, F. and Beekin, E. (2003). De 'gezondheid' van Nederland: Sterftetrends en sterfteverschillen in de negentiende en twintigste eeuw ['Health' in the low countries: Differences in mortality trends in the 19th and 20th centuries]. In: Beekink, E., Boonstra, T., and Knippenberg, H. (eds.). *Nederland in verandering: Maatschappelijke ontwikkelingen in kaart gebracht, 1800–2000* [*Changes in the low countries: Social developments, 1800–2000*]. Amsterdam: Aksant: 71–94.

Van Poppel, F., Reher, D., Sanz-Gimeno, A., Sánchez-Domínguez, M., and Beekink, E. (2012). Mortality decline and reproductive change during the Dutch demographic transition: Revisiting a traditional debate with new data. *Demographic Research* 27(11): 299–338. doi:10.4054/DemRes.2012.27.11.

Vishnevsky, A.G. and Sakevich, V.I. (2006). *Demographic modernization of Russia, 1900–2000.* Moscow: New Publishing House: 195–246.

Wadhera, S. and Strachan, J. (1993). Selected birth and fertility statistics, Canada, 1921–1990. Ottawa: Statistics Canada, Canadian Centre for Health Information.

Watkins, S. (1986). Conclusions. In: Coale, A. and Watkins, S. (eds.). *The decline of fertility in Europe*. Princeton: Princeton University Press: 420–449.

Weir, D. (1994). New estimates of nuptiality and marital fertility in France, 1740–1911. *Population Studies* 48: 307–331. doi:10.1080/0032472031000147816.

Woods, R. (1997). Causes of death in England and Wales, 1851–1860 to 1891–1900: The decennial supplements [computer file]. Colchester: UK Data Archive.

Wrigley, E. (1978). Marital fertility in seventeenth-century Colyton: A note. *Economic History Review* 31(3): 429–436. doi:10.2307/2598764.

Wrigley, E. (1985a). The fall of marital fertility in nineteenth-century France: Exemplar or exception? (Part I). *European Journal of Population* 1(1): 31–60. doi:10.1007/BF01796917.

Wrigley, E. (1985b). The fall of marital fertility in nineteenth-century France: Exemplar or exception? (Part II). *European Journal of Population* 1(2–3): 141–177. doi:10.1007/BF01796931.

Wrigley, E., Davies, R., Oeppen, J., and Schofield, R. (1997). *English population history from family reconstitution, 1580–1837*. Cambridge: Cambridge University Press. doi:10.1017/CBO9780511660344.

Wrigley, E. and Schofield, R. (1981). *The population history of England, 1541–1871: A reconstruction.* Cambridge: Harvard University Press.

Appendix

Figure A-1: Historical trends in $_{25}q_0$ (both sexes; five years moving average)

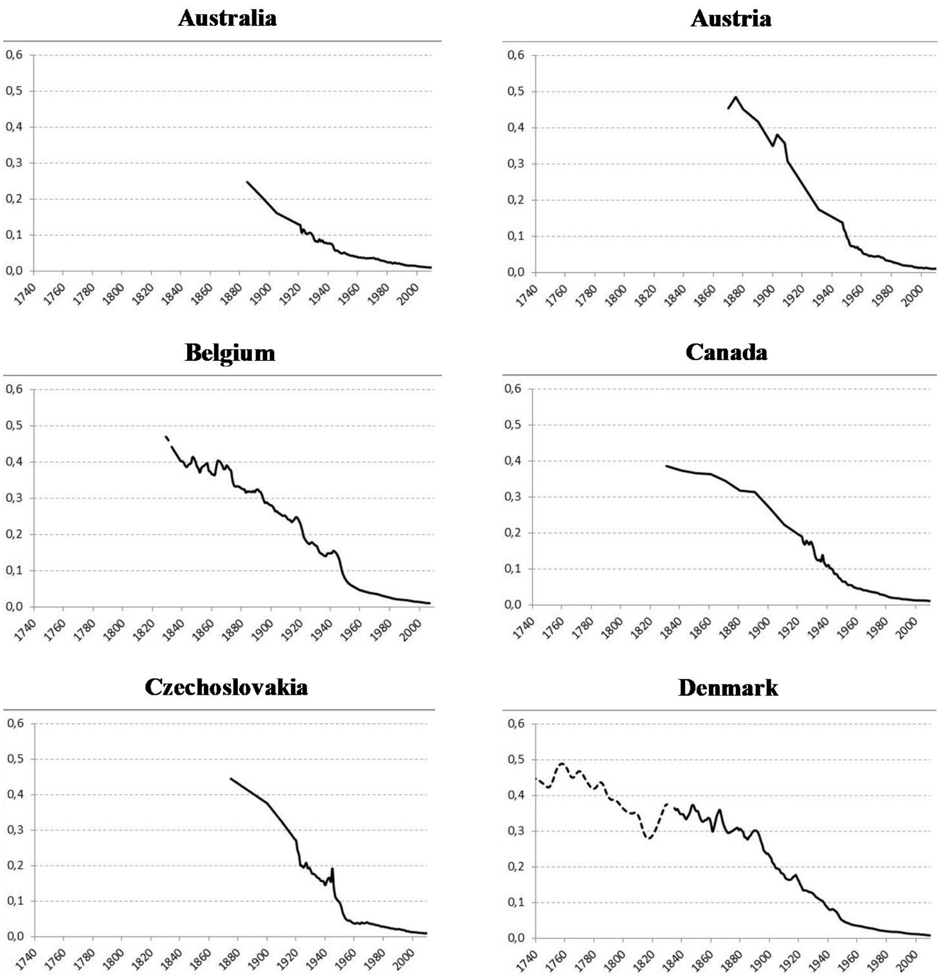


Figure A-1: (Continued)

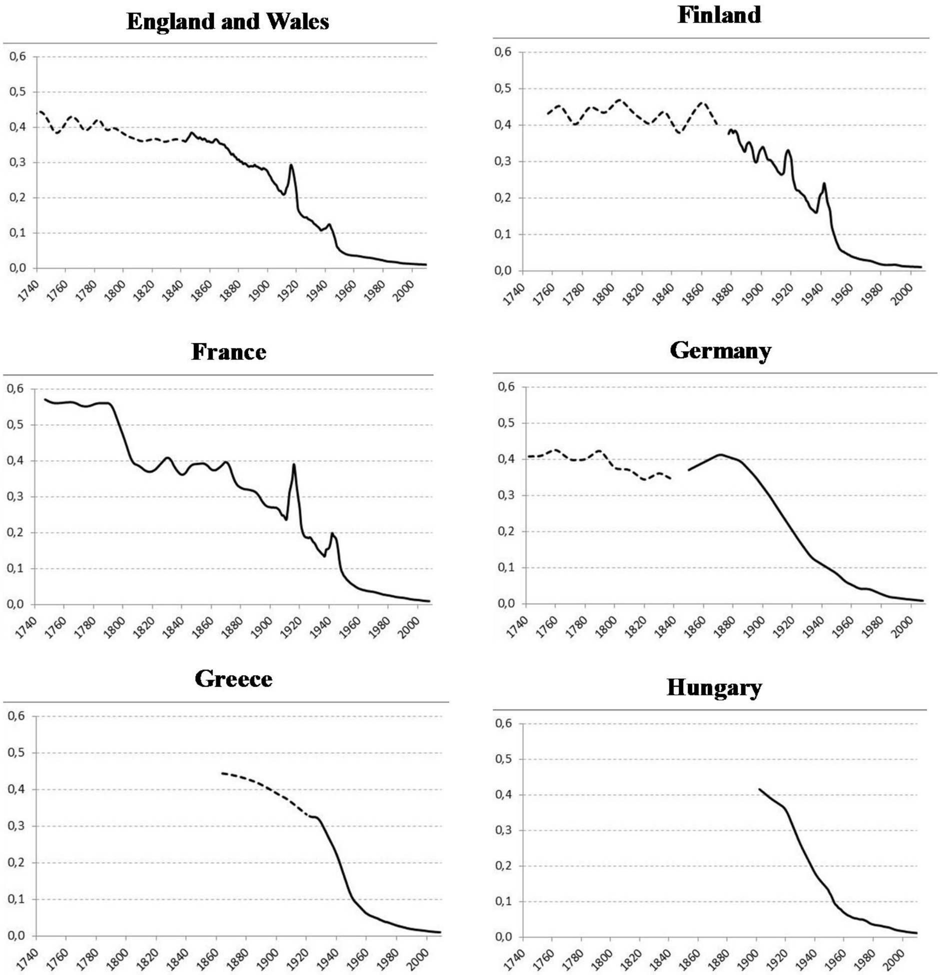


Figure A-1: (Continued)

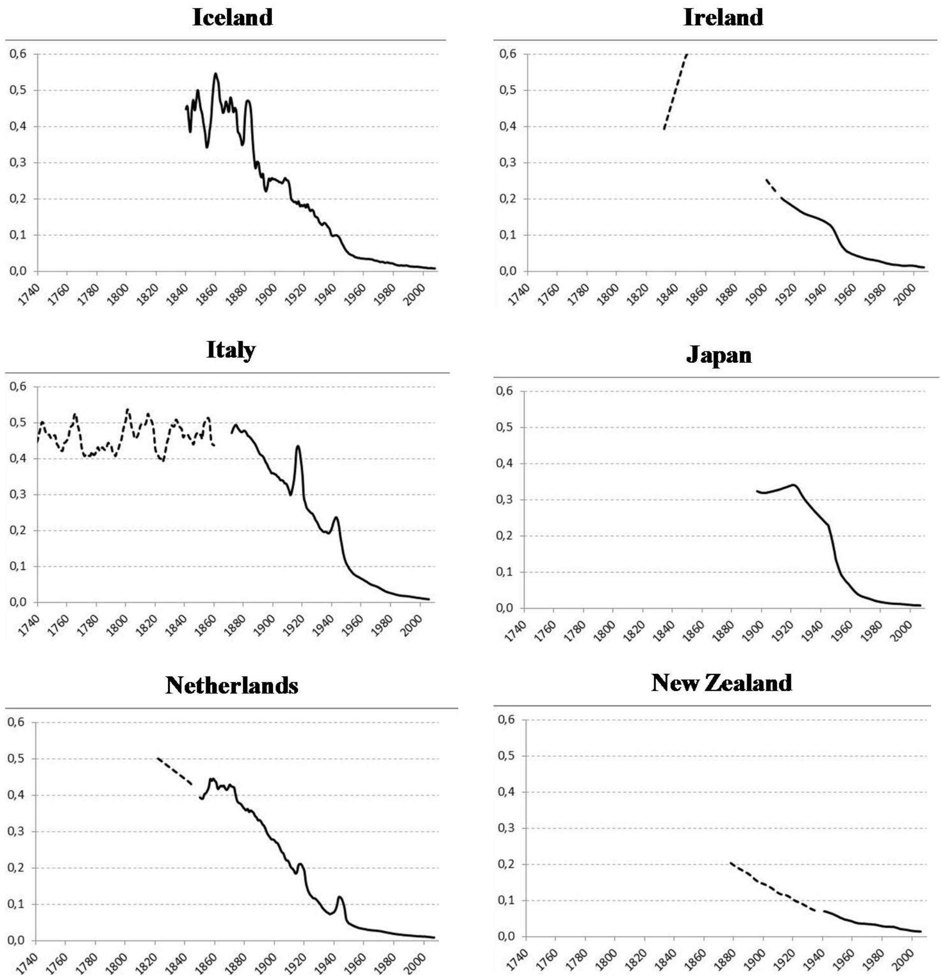


Figure A-1: (Continued)

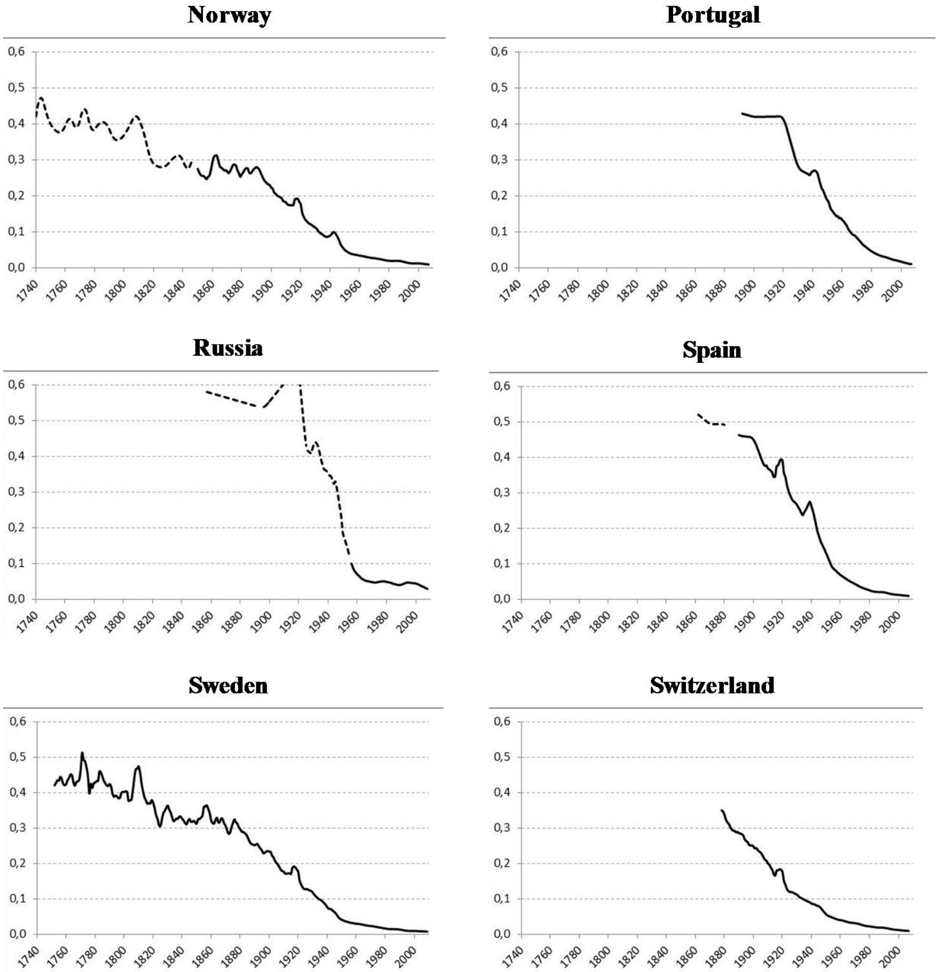
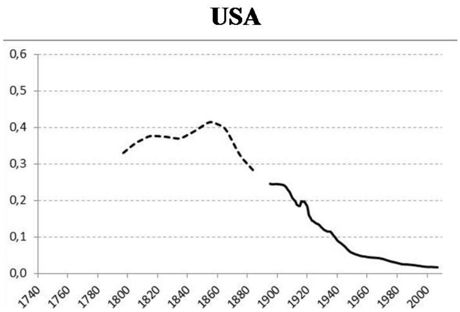


Figure A-1: (Continued)



Notes: The values estimated using various procedures explained in the bibliography for each country in Table A-2 are shown with a dotted line. This data should therefore be treated with due caution, since its reliability is not equivalent to that of the data represented using unbroken lines. In the case of Italy, the dotted line only refers to the north of the country.

Figure A-2: Historical trends in several demographic indices, 1880–1980

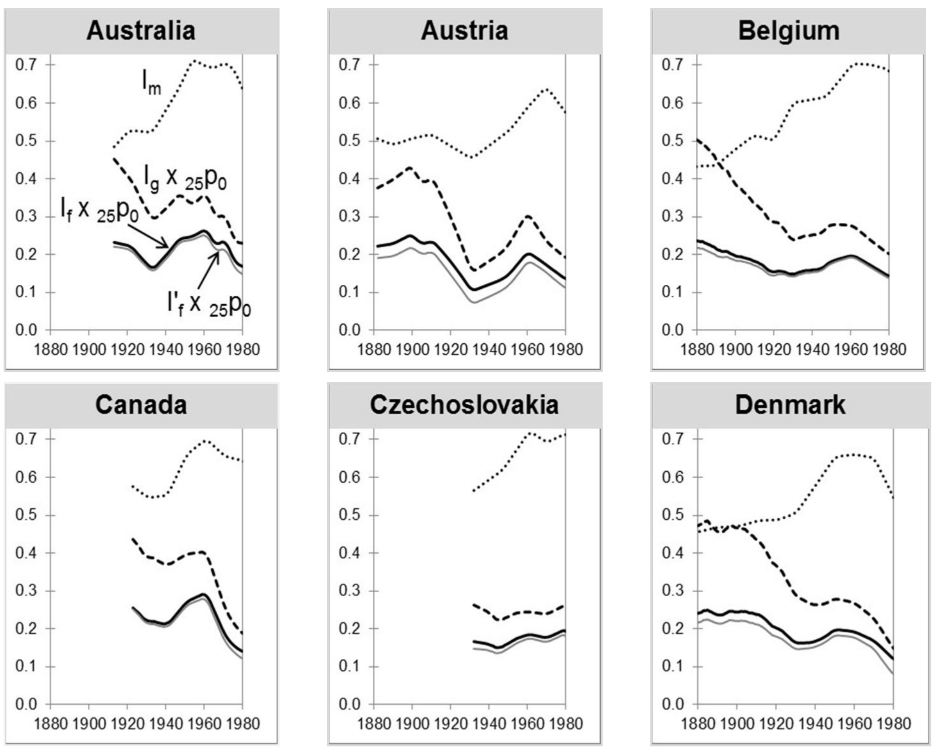


Figure A-2: (Continued)

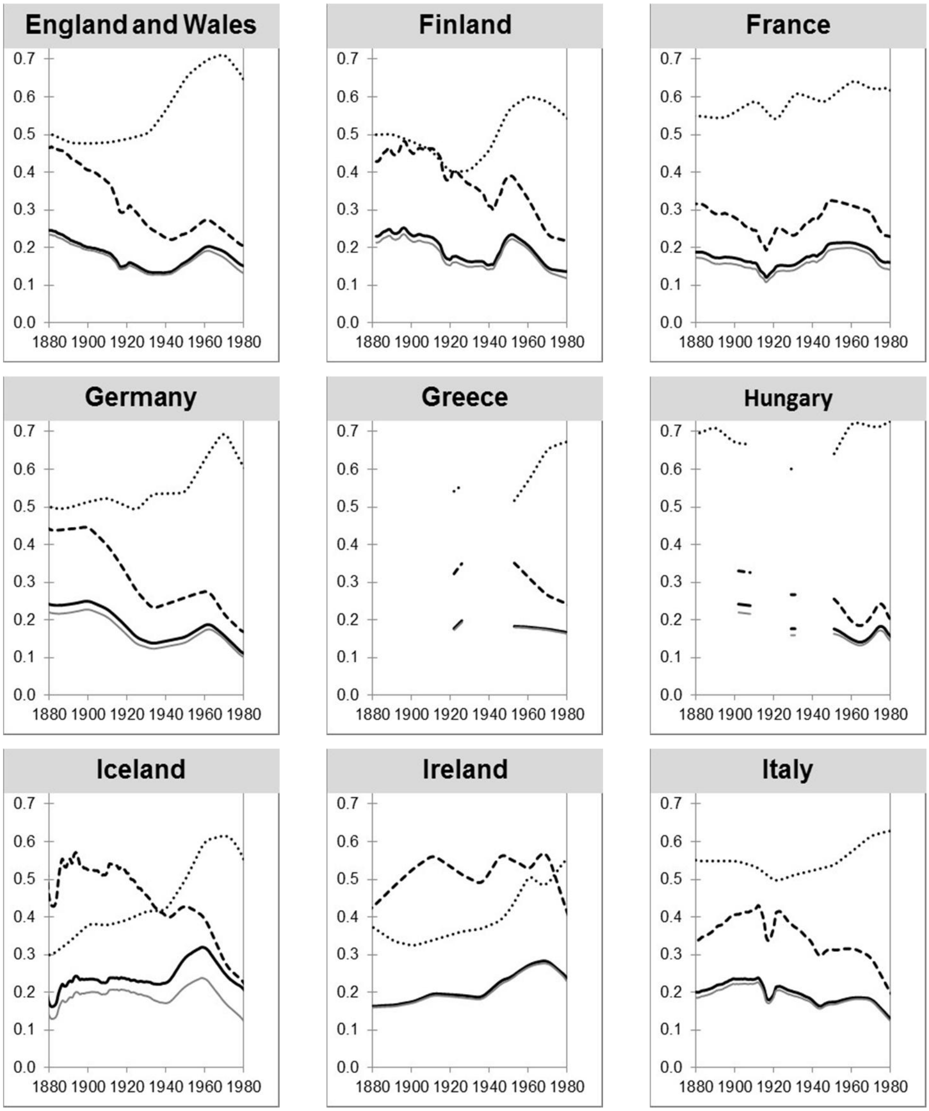


Figure A-2: (Continued)

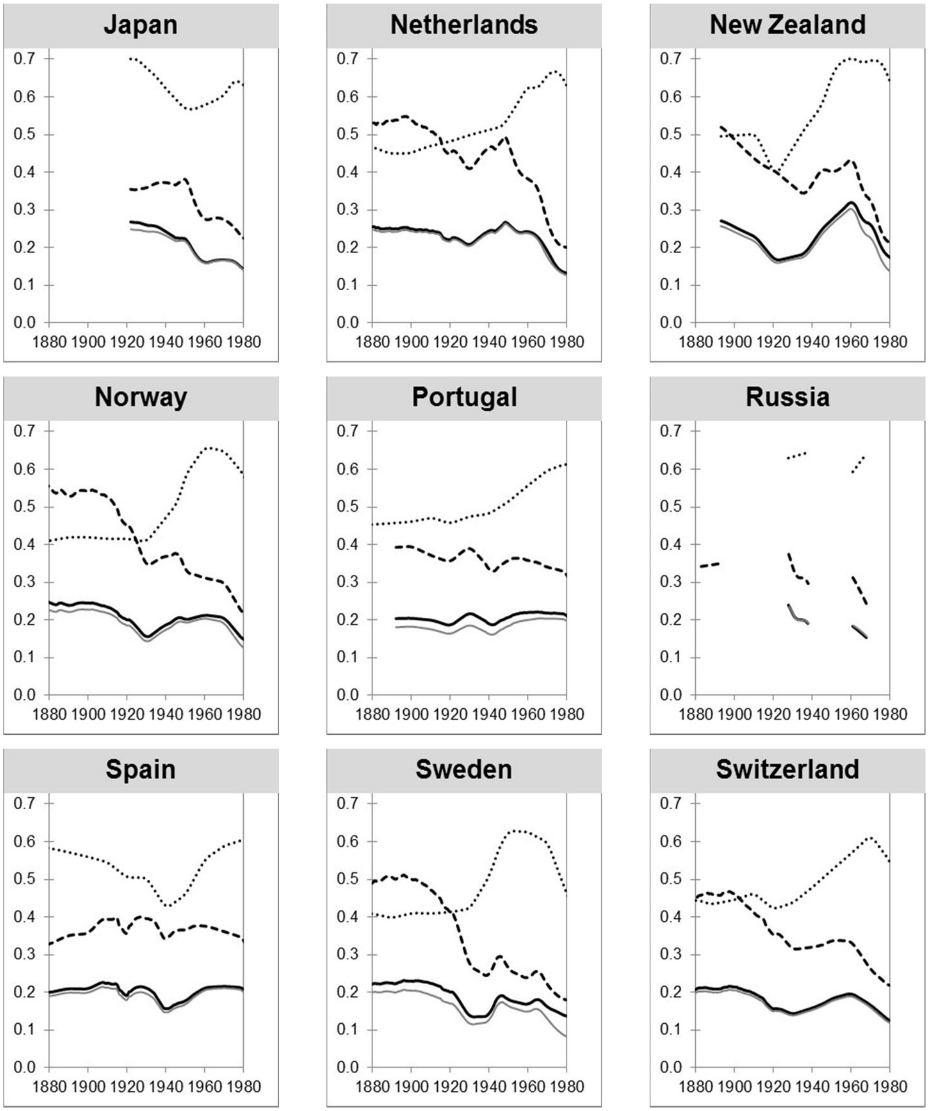


Figure A-2: (Continued)

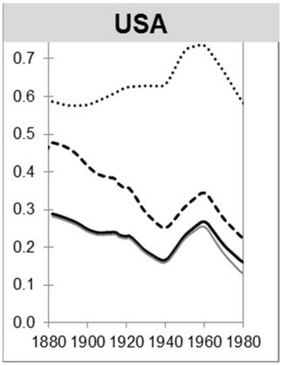
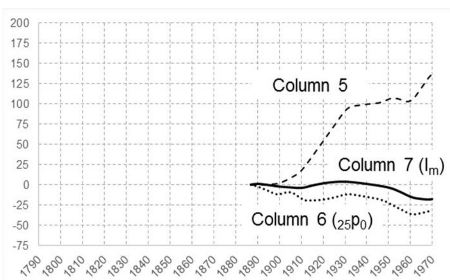


Figure A-3: Estimate of the influence of variables I_g, $_{25}p_0$, and I_m on the evolution of the index of net total reproduction ($I'_f \times {}_{25}p_0$) over the demographic transition period. Annual trends in columns 5, 6, and 7 of Table 4

Austria



Belgium

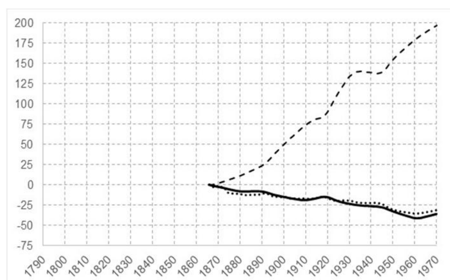


Figure A-3: (Continued)

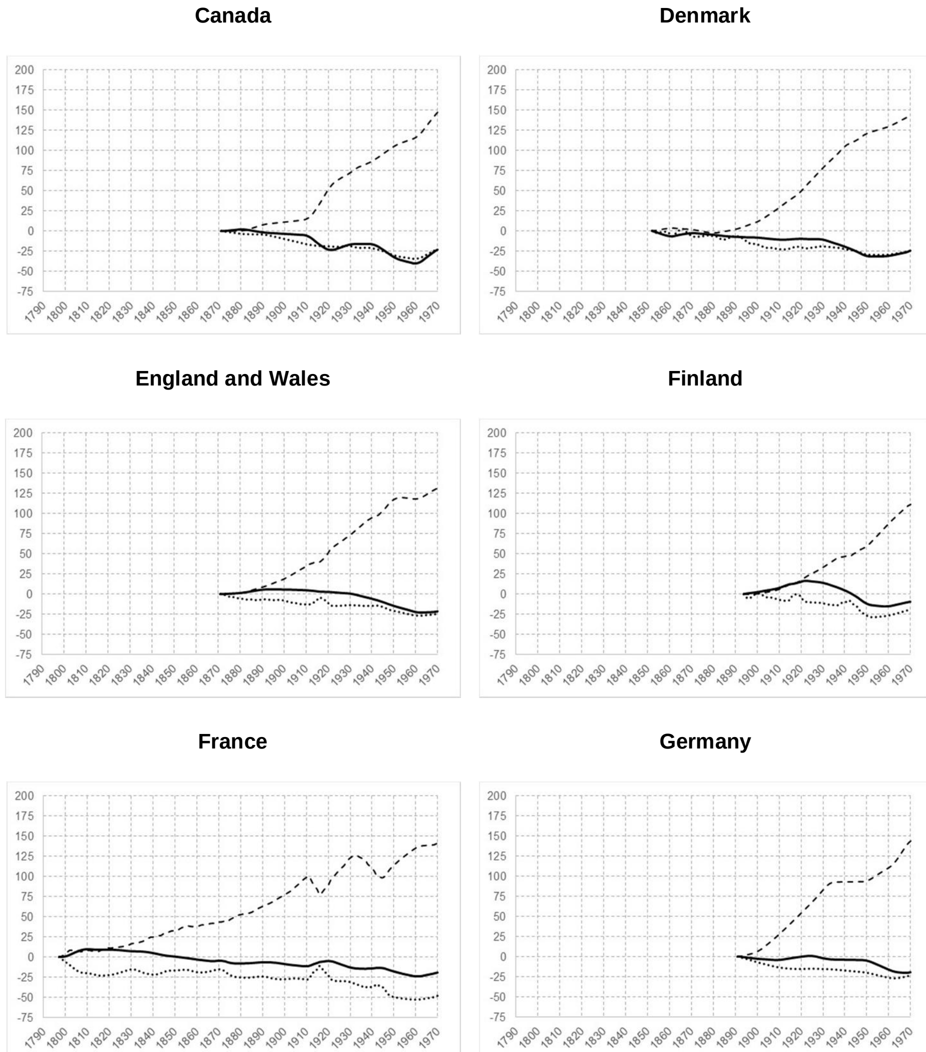


Figure A-3: (Continued)

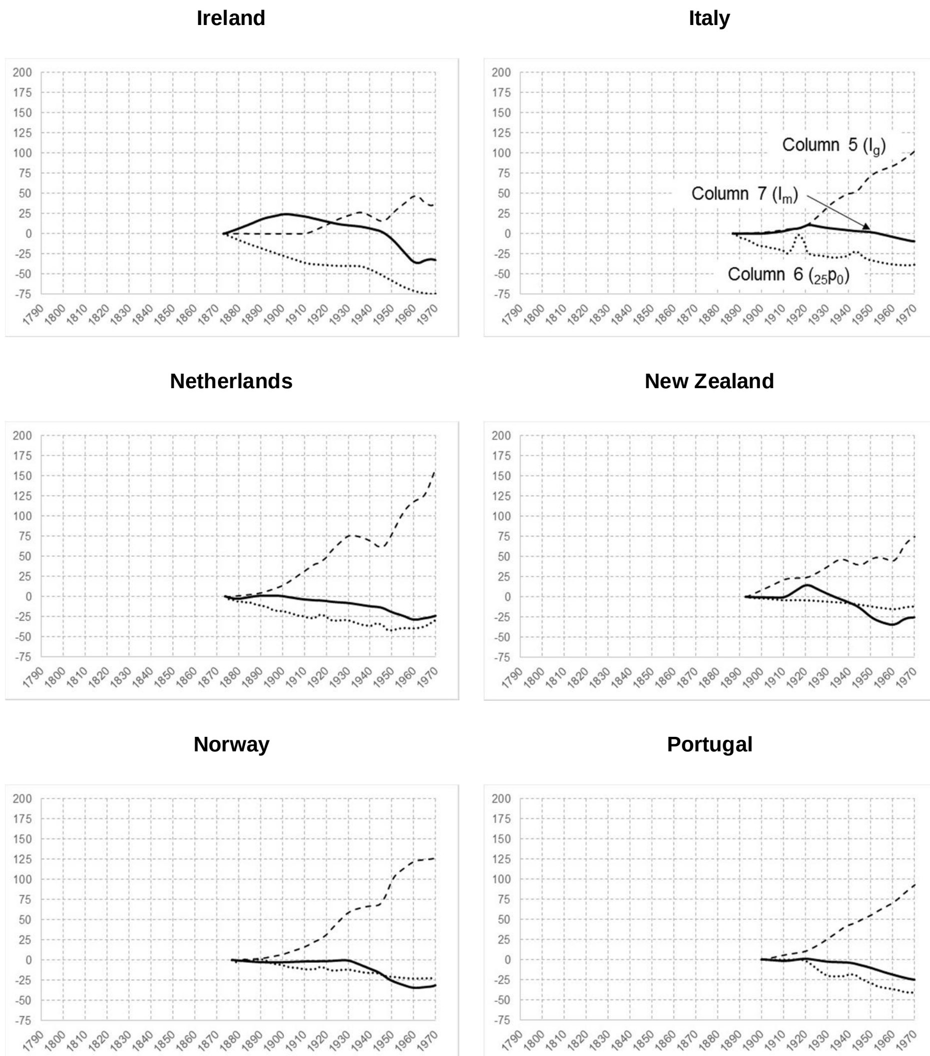
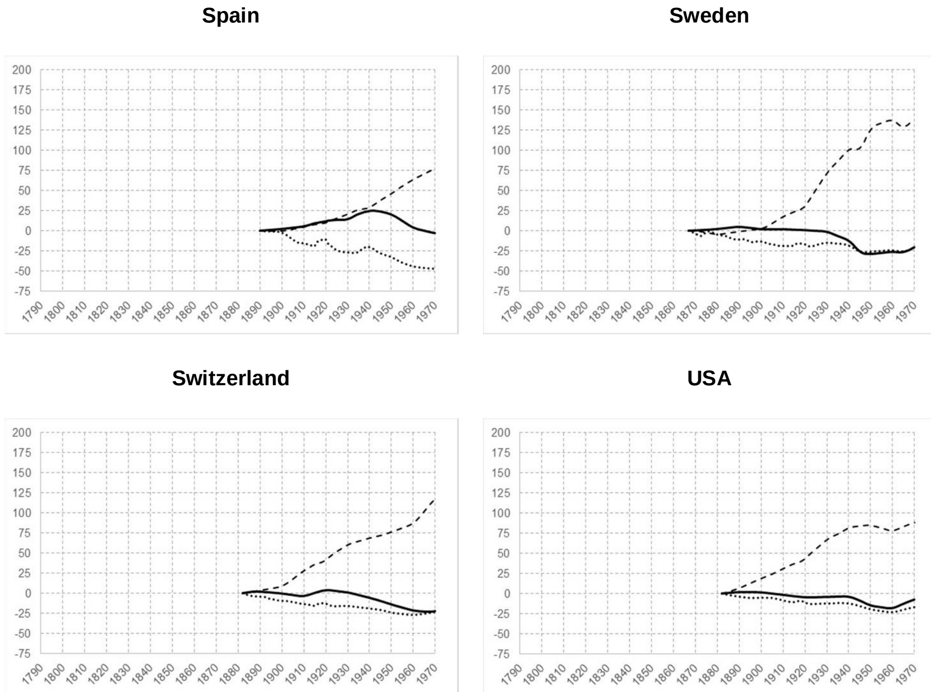


Figure A-3: (Continued)



Data sources

Princeton indices (If, Ig, Im)

The provincial and national values for the various Princeton indices were obtained from Coale and Watkins (1986). The data is available from the following University of Princeton website: http://opr.princeton.edu/archive/pefp/. The author of the present paper calculated the indices for Table A-1. The Princeton Indices are based on census data; that is, on data collected every ten years or so: Therefore, use is made of linear interpolation between census dates.

Table A-1: Countries and years for which Princeton indices were not available and were calculated by author or obtained from alternative source

	Provincial level	National level
Australia		Calculated by the present author: 1911, 1921, 1933, 1947, 1954, 1966, 1971, 1976, 1981, 1986, 1991, 1996, 2001, 2006
Austria		Calculated by the present author: 1951, 1991, 2001
Belgium		Calculated by the present author: 1992, 1996, 2000, 2005, 2010
Canada		From 1852 to 1911 the data is from Quebec, obtained from Pouyez and Lavoie (1983); Calculated by the present author: 1921, 1931, 1941, 1951, 1961, 1971, 1976, 1981, 1986, 1991, 1995, 2001, 2006, 2011
Czechoslovakia		Calculated by the present author: 1947, 1985, 1990, 1995, 2000, 2005, 2010
Denmark		1840 and 1847, Matthiessen (1985); Calculated by the present author: 1950, 1981, 1940, 1990, 1995, 2000, 2005, 2010
England and Wales	Calculated by the present author: 1951, 1961	From 1543 to 1850 using inverse projection techniques, Anderson et al. (2001); Calculated by the present author: 1939, 1951, 1991, 1995, 2001, 2010
Finland		Calculated by the present author: 1991, 2001, 2011
France	Calculated by the present author: 1946, 1968, 1982	From 1740 to 1911, Weir (1994); Calculated by the present author: 1946, 1954, 1975, 1990, 1999, 2004, 2008
Germany		Calculated by the present author: 1946, 1950, 1991, 1996, 2001, 2006, 2010
Greece		Calculated by the present author: 1920, 1981, 1991, 2001
Hungary		Calculated by the present author: 1949, 1965, 1975, 1985, 1990, 2001, 2005, 2010
Iceland		Calculated by the present author: 1971, 1975, 1980, 1985, 1990, 1995, 2000, 2006, 2010
Ireland		Calculated by the present author: 1946, 1951, 1966, 1986, 1991, 1996, 2002, 2006
Italy	Calculated by the present author: 1971, 1981, 1991, 2001	Calculated by the present author: 1981, 1991, 2001, 2006, 2010
Japan		Calculated by the present author: 1920, 1925, 1930, 1935, 1940, 1950, 1955, 1960, 1965, 1970, 1975, 1980, 1985, 1990, 1995, 2000, 2005, 2010
Netherlands		Calculated by the present author: 1947, 1955, 1965, 1975, 1985, 1990, 1995, 2000, 2005, 2010
New Zeland		Calculated by the present author: 1891, 1911, 1921, 1936, 1945, 1951, 1956, 1961, 1966, 1971, 1976, 1981, 1986, 1991, 1996, 2001, 2006
Norway		Calculated by the present author: 1801, 1866, 1911, 1946, 1950, 1990, 1995, 2000, 2005, 2011
Portugal	Calculated by the present author: 1970, 1981	Calculated by the present author: 1991, 2001, 2011
Russia		Calculated by the present author: 1989, 2002, 2010
Spain	Calculated by the present author: 1970, 1981, 1991, 2001	Calculated by the present author: 1860, 1877, 1950, 1991, 2001, 2006, 2011
Sweden		Calculated by the present author: 1750, 1800, 1850, 1870, 1890, 1910, 1920, 1940, 1945, 1965, 1970, 1975, 1980, 1985, 1990, 1995, 2000, 2005, 2010
Switzerland		Calculated by the present author: 1980, 1985, 1990, 1995, 2000, 2005, 2010
United States		The I_g values for the years 1848, 1858, 1868 and 1878 from Hacker (2003); Calculated by the present author: 1880, 1890, 1900, 1910, 1920, 1930, 1940, 1950, 1960, 1970, 1980, 1990, 2000, 2006, 2010

$_{25}q_0$ (both sexes)

Table A-2: Countries and years for which Princeton indices were not available and were calculated by author or obtained from alternative source

	Provincial level	National level
Australia		From 1885 to 1905 (indigenous population excluded in 1885), Australian Bureau of Statistics (http://www.abs.gov.au/); from 1921 to 2007, Human Mortality Database HMD (www.mortality.org)
Austria		From 1870 to 1931, Human Life-Table Database HLTD (http://www.lifetable.de/cgi–bin/datamap.plx); from1947 to 2008, HMD
Belgium		From 1827 to 1832, estimated from the e_0 provided by Quetelet (1851) taking into account the Regional Model Life Tables "West" by Coale and Demeny (1983); from 1841 to 2007, HMD.
Canada	From 1921 to 2009, Canadian Human Mortality Database CHMD (http://www.bdlc.umontreal.ca/chmd/prov/que/que.htm)	From 1831 to 1911, Bourbeau, Légaré, and Émond (1997); from 1921 to 2007, HMD
Czechoslovakia		From 1875 to 1937 estimated from the e_0 provided by Srb (1962) taking into account the Regional Model Life Tables "East" by Coale and Demeny (1983); from 1920 to 1949, HLTD; from 1950 to 2008, HMD
Denmark		From 1665 to 1835 using inverse projection techniques, estimated from the values for e_0 provided by Johansen (2002) and Johansen and Oeppen (2001) taking into account the Regional Model Life Tables "West" by Coale and Demeny (1983); from 1782 to 1832, estimated using e_0 provided by Andersen (1979) taking into account the Regional Model Life Tables "West" by Coale and Demeny (1983); from 1835 to 2008, HMD
England and Wales	From 1855 to 1895, calculated by the present author on the basis of data from Woods (1997); from 1911 to 1951, calculated by the present author	From 1541 to 1870 using inverse projection techniques, estimated from the e_0 values provided by Wrigley et al. (1997), and taking into account the third English life table by Wrigley and Schofield (1981: 714); from 1841 to 2006 (England and Wales), HMD.
Finland		From 1751 to 1875, Turpeinen and Kannisto (1997); from 1878 to 2008, HMD
France	From 1806 to 1901, Bonneuil (1997); from 1911 to 1999, calculated by the present author	1745, Vallin (1991); from 1752 to 1802, Blayo (1975); from 1806 to 1901, Bonneuil (1997); from 1902 to 2007, HMD
Germany	From 1875 to 1925, Imhof (1990)	From 1810 to 1850, Imhof (1990); from 1871 to 1933, HLTD; 1950 (only West Germany), HLTD; from 1956 to 2008, HMD.
Greece		From 1850 to 1922 estimated from e_0 provided by Siampos (1989) taking into account the Regional Model Life Tables "South" by Coale and Demeny (1983); from 1928 to 2002, HLTD

Table A-2: (Continued)

	Provincial level	National level
Hungary		From 1900 to 1941, Hungarian Central Statistical Office (1992); from 1950 to 2006, HMD
Iceland		From 1838 to 2008, HMD
Ireland		1830 and 1848 estimated from e_0 provided by Boyle and Ó Gráda (1986) taking into account the Regional Model Life Tables "West" by Coale and Demeny (1983); 1901 and 1911 estimated from e_0 provided by Ó Gráda (1979) taking into account the Regional Model Life Tables "West" by Coale and Demeny (1983); from 1926 to 1946, HLTD; from 1950 to 2006, HMD
Italy	From 1871 to 1971, calculated by the present author; from 1974 to 2008, National Statistics Institute of Italy ISTAT (http://demo.istat.it//unitav/index.html?lingua=eng)	From 1650 to 1881 (only North Italy) using inverse projection techniques, estimated from e_0 obtained in the annual inverse projection carried out by Galloway (1994) taking into account the Regional Model Life Tables "West" by Coale and Demeny (1983); from 1872 to 2006, HMD.
Japan		From 1895 to 1935, HLTD; from 1947 to 2008, HMD.
Netherlands	From 1850 to 1960, van Poppel and Beekink (2003)	From 1820 to 1846, estimated from e_0 provided by Rothenbacher (2002) taking into account the Regional Model Life Tables "West" by Coale and Demeny (1983); from 1850 to 2008, HMD.
New Zealand		From 1876 to 1941 (only the non–Maori population), estimated from e_0 provided by Pool (1982, 1985, 1993) and Pool and Cheung (2003, 2005) taking into account the Regional Model Life Tables "West" by Coale and Demeny (1983); 1936, Statistics New Zealand (http://www.stats.govt.nz/); from 1948 to 2008, HMD
Norway		From 1738 to 1843, estimated using the Regional Model Life Tables "North" by Coale and Demeny (1983) from e_0 calculated by Brunborg (1976); from 1846 to 2008, HMD
Portugal	From 1914 to 1940, calculated by the present author; from 1941 to 1982, Centro de Estudos Demográficos (1976); Carrilho (1980) and Cónin, Marques, and Pinto (1988)	From 1890 to 1920, Rodrigues Veiga, Guardado Moreira, and Fernandes (2004); 1930, Nazareth (1977); from 1940 to 2009, HMD
Russia		1885 (Russia), estimated from e_0 provided by Blum and Troitskaja (1996) and taking into account the Regional Model Life Tables "East" by Coale and Demeny (1983); from 1896 to 1958 (Russia), HLTD; from 1959 to 2008 (Russia), HMD
Spain	1866, estimated using the Regional Model Life Tables "South" by Coale and Demeny (1983) from e_0 calculated by Dopico (1987); from 1900 to 1930, Dopico and Reher (1998); 1940 and 1950, calculated by the present author; from 1960 to 2001, Blanes (2007)	From 1860 to 1890, estimated using the Regional Model Life Tables "South" by Coale and Demeny (1983) from e_0 calculated by Dopico (1987) and Livi-Bacci (1968); 1900, Dopico and Reher (1998); from 1908 to 2006, HMD.
Sweden	From 1861 to 1971, calculated by the present author using information from Hofsten and Lundström (1976)	From 1751 to 2007, HMD
Switzerland		From 1876 to 2008, HMD
United States		From 1795 to 1895 (only Caucasian population), Hacker (2010); from 1906 to 1930, HLTD; from 1933 to 2007, HMD

Total fertility rate

Table A-3: Sources of information concerning the total fertility rate (five years moving average)

	National level
Australia	From 1850 to 1905 estimated from the crude birth rates (CBR) obtained from the Australian Bureau of Statistics (www.abs.gov.au) using a conversion rate of 0.134 (Bogue 1993); from 1908 to 1918 Chesnais (1992); from 1921 to 2010 Australian Bureau of Statistics.
Austria	From 1868 to 1898 Chesnais (1992); from 1903 to 1908 and from 1937 to 1959 Sardon (1991); from 1960 to 2010 Eurostat (ec.europa.eu/eurostat).
Belgium	From 1830 to 1850 estimated from the CBR obtained by Chesnais (1992) using a conversion rate of 0.1461 (Bogue 1993); from 1853 to 1900 Chesnais (1992); from 1910 to 1920 estimated from the If calculated by Coale and Watkins (1986) applying a conversion rate of 12.44 as Sardon (1996) suggests; from 1930 to 1959 Sardon (1991); from 1960 to 2010 Eurostat.
Canada	From 1825 to 1845 (only for the province of Quebec) and from 1850 to 1860 data estimated from the CBR calculated by Henripin (1972) applying a conversion rate of 0.134 (Bogue 1993); from 1871 to 1902 Needleman (1986); from 1906 to 1920, Chesnais (1992); from 1921 to 1990 Wadhera and Strachan (1993); from 2000 to 2010 Statistics Canada CASIM (http://www5.statcan.gc.ca/cansim/a26).
Czechoslovakia	From 1870 to 1919 estimated from the CBR obtained from the Czech Statistical Office (www.czso.cz) using a conversion rate of 0.134 (Bogue 1993); from 1920 to 2010, Czech Statistical Office and Statistical Office of the Slovak Republic (slovak.statistics.sk).
Denmark	From 1665 to 1835 Johansen and Oeppen (2001); from 1850 to 1898 Johansen (2002); from 1901 to 2010 Statistics Denmark (www.statbank.dk).
England and Wales	From 1543 to 1840 Wrigley, et al. (1997); from 1843 to 1959 (England and Wales) and from 1960 to 2010 (United Kingdom), UK National Statistics (www.statistics.gov.uk)
Finland	From 1755 to 1765 estimated from the CBR provided by Lutz (1987) using a conversion rate of 0.14285 (Bogue 1993); from 1776 to 2010 Statistics Finland (tilastokeskus.fi).
France	1745 estimated from the I_f calculated by Weir (1994) applying a conversion rate of 12.44 as Sardon (1996) suggests; from 1750 to 1900 Chesnais (1992); from 1901 to 2010 National Institute of Statistics and Economic Studies of France (www.insee.fr).
Germany	From 1817 to 1820 estimated from the CBR provided by Chesnais (1992) using a conversion rate of 0.1346 (Bogue 1993); from 1825 to 1875 estimated from the Gross Reproductive Rates calculated by Chesnais (1992) (TFR = GRR / 0.4886); from 1883 to 1930 Chesnais (1992); from 1931 to 1955 (only West Germany) Chesnais (1992); from 1956 to 2010 Human Fertility Database (www.humanfertility.org) (HFD).
Greece	From 1931 to 1936 Sardon (1991); from 1950 to 1959 Chesnais (1992); from 1960 to 2010 Eurostat.
Hungary	From 1861 to 1899 estimated from the CBR calculated by Chesnais (1992) applying a conversion rate of 0.1221 (Bogue 1993); from 1900 to 1920 Kollega (1996); from 1921 to 1959 Chesnais (1992); from 1960 to 2010 Eurostat.
Iceland	From 1838 to 1852 estimated from the CBR provided by Statistics Iceland (www.statice.is) applying a conversion rate of 0.14285 (Bogue 1993); from 1853 to 2009 Statistics Iceland.
Ireland	From 1822 to 1841 estimated from the CBR provided by Boyle and Ó Gráda (1986) and from 1865 to 1925 estimated from the CBR provided by Chesnais (1992) applying a conversion rate of 0.134 (Bogue 1993); from 1926 to 1959 Sardon (1991); from 1960 to 2010 Eurostat.

Table A-3: (Continued)

	National level
Italy	From 1650 to 1881 (only North Italy) estimated from the GRR obtained by Galloway (1994); from 1873 to 1898 Chesnais (1992); from 1903 to 1959 Sardon (1991); from 1960 to 2010 Eurostat.
Japan	From 1892 to 1919 estimated from the CBR from Statistics Bureau of Japan (www.stat.go.jp) applying a conversion rate of 0.1478 (Bogue 1993); from 1920 to 1943 Taeuber (1958); from 1947 to 2010 Statistics Bureau of Japan.
Netherlands	From 1840 to 1849 estimated from the CBR from Chesnais (1992) applying a conversion rate of 0.146 (Bogue 1993); from 1853 to 1898 Chesnais (1992); from 1900 to 2010 Centraal Buerau voor de Statistiek (statline.cbs.nl).
New Zealand	From 1861 to 1920 (only non–Maori population) estimated from the CBR from Statistics New Zealand (www.stats.govt.nz) applying a conversion rate de 0.134 (Bogue 1993); from 1921 to 2010 Statistics New Zealand.
Norway	From 1735 to 1850 estimated from the CBR from Statistics Norway (www.ssb.no) applying a conversion rate of 0.439 (Bogue 1993); from 1851 to 1960 Chesnais (1992); from 1961 to 1973 Eurostat; 1974 to 2010 Statistics Norway (www.ssb.no).
Portugal	From 1886 to 1932 estimated from the CBR from Chesnais (1992) applying a conversion rate of 0.13 (Bogue 1993); from 1933 to 1959 Sardon (1991); from 1960 to 2010 Eurostat.
Russia	From 1843 to 1853 estimated from the CBR calculated by Rédei (1960) and from 1861 to 1897 estimated from the CBR from Chesnais (1992) applying a conversion rate of 0.134 (Bogue 1993); from 1898 to 1918 Vishnevsky and Sakevich (2006); from 1920 to 1958 Andreev, Darskij, and Kharkova (1992); from 1959 to 2010 HFD.
Spain	From 1858 to 1900 estimated from the CBR from Chesnais (1992) applying a conversion rate of 0.1323 (Bogue 1993); from 1901 to 1974 Sardon (1991); from 1975 to 2010 Instituto Nacional de Estadística (www.ine.es).
Sweden	From 1750 to 1969 Hofsten and Lundström (1976); from 1970 to 2010 Statistics Sweden (www.ssd.scb.se).
Switzerland	From 1870 to 1930 Calot et al. (1998); from 1932 to 1959 Sardon (1991); from 1960 to 2009 Eurostat.
United States	From 1800 to 1830 (only white population) Haines and Steckel (2000); from 1837 to 1877 Hacker (2003); from 1880 to 1890 (only white population) Haines and Steckel (2000); from 1903 to 1932 Chesnais (1992); from 1933 to 2010 HFD.

Illegitimate births

INED database (Developed countries demography):
https://www.ined.fr/en/everything_about_population/data/online-databases/developed-countries-database/
Mitchell (2007a, 2007b, 2007c).

Net reproduction rate (NRR)

1950–2009: United Nations, Department of Economic and Social Affairs, Population Division (2015).
Denmark, 1906–1936: Glass (1940),
England, 1541–1871: Wrigley et al. (1997: 664),

England and Wales, 1870–1922: Hogben (1938: 62–65); 1932–1938: Kuczynski (1942); 1964–1971: Campbell (1973); 1988–2009: Office for National Statistics (https://www.ons.gov.uk/).
France, Germany, and Italy 1901–1949: Chesnais (1998: 90),
Germany 1881–1900: Lotka (1936),
Sweden, 1816–1949: Hyrenius (1951).
USA, 1935–1950: US Department of Health, Education, and Welfare (1950).