Mortality–fertility synergies during the demographic transition in the developed world

Jesús J. Sánchez-Barricarte
Carlos III University of Madrid

The classic theory used to explain the demographic transition assumes that mortality is the key explanatory variable influencing the decline in fertility. However, the empirical results obtained in what is known as the Princeton European Fertility Project have led many specialists to question this assumption. Using both national and provincial aggregated data for 25 countries over a long time span, the analysis reported in this paper found that mortality does indeed play a fundamental role in accounting for the main demographic changes that occurred both before and during the transitional period. Others’ research based on individual data has shown clearly that the number of surviving children was indeed an important factor for reproductive decisions. My analysis, using aggregated data, reached largely similar conclusions regarding the role of mortality in changing reproductive trends, via its impact on nuptiality and marital fertility at different stages of the demographic transition.

Keywords: demographic transition; fertility; mortality; nuptiality; natural fertility; historical demography; European Fertility Project; developed countries

Introduction

The classic theory concerning the demographic transition (Davis 1945; Notestein 1945) provides a framework that is intended to explain one of the cornerstones of modern societies. In the theory’s original form, a decline in mortality is understood as a prerequisite for any long-term reduction in fertility. According to this premise, societies develop from a situation of high mortality and fertility to one with low rates of both, through a process in which a decrease in the former precedes a decline in the latter. In short, the relationship between mortality and fertility lies at the heart of the model of the demographic transition. However, despite the vast number of studies carried out on this topic over many decades, there is still considerable disagreement between researchers on the role that mortality plays in bringing about the general decline in fertility. Many of these criticisms have been voiced within the context of what is known as the Princeton European Fertility Project (PEFP). This project had two objectives: first, to create a quantitative record of the European fertility transition that occurred within the past two centuries in almost all European provinces, and second, to determine the social and economic circumstances that prevailed when the modern decline in fertility began, in the hope of elucidating the causal mechanisms of the fertility transition. Surprising as it may seem, the empirical research carried out to date in the field of historical demography has yielded ambiguous or even contradictory results (Reher 1999; Reher et al. 2008).

One of the main conclusions set forth at the end of the PEFP was expressed as follows: ‘At the end of this quest, we cannot report that the historical evidence confirms that the declines of infant mortality led to the decline of fertility’ (Van de Walle 1986, p. 233). Many other researchers have reached the same conclusions (Knodel 1974, pp. 167–85; Lesthaeghe 1977, pp. 171–6; Teitelbaum 1984; Watkins 1986, p. 436; Haines 1998). Indeed, in a study on the state of the research concerning the transition and the theory of fertility, Van de Kaa (1996, p. 409) concluded: ‘Notestein’s notion that a mortality reduction would automatically lead to a
significant decline in fertility through a series of pre-existing social mechanisms is untenable.’

Some researchers have stressed the importance of mortality in the demographic transition (studies based on aggregated data: Reher and Napal 1989; Galloway et al. 1998; Reher 1999; studies based on individual data: Reher and Sanz-Gimeno 2007; Schellekens and van Poppel 2012; Van Poppel et al. 2012). However, the general impression among a large number of demographers is that mortality is not a particularly promising explanatory variable when it comes to accounting for the historical decline in fertility.

Although it would be difficult to prove definitively that there is a connection between mortality and fertility, compelling evidence leads me to suppose that such a relationship exists. ‘Certainly, reduced mortality and morbidity and a healthier population are major contributors to a rise in living standards, which are often regarded as a major factor in fertility decline’ (Kirk 1996, pp. 368–9). In other words, the decline in mortality made modernization possible, encouraging economic productivity alongside a decrease in fertility.

Societies with high fertility and low mortality, or high mortality or low fertility, are extremely rare and transitory. In general, mortality and fertility have always adjusted to each other to give rise to moderate population growth.

According to Reher (1999, pp. 12–3), the decrease in infant mortality may have affected fertility rates through various mechanisms. First, the death of a baby in the first months of life tended to boost fertility, historically speaking, since the mother would have to stop breastfeeding, and would therefore no longer be protected from conception by its inhibitory effects on fertility. Second, parents who lost a child would naturally try to replace it with another, until they reached the desired number of surviving children for their family. Finally, the significant drop in infant mortality left many couples with an excess of surviving children. Parents were conscious of the negative economic effects of having too many children, both in terms of the family’s standard of living and in terms of future inheritance. In view of this situation, couples chose to limit or prevent pregnancies (normally, people only became aware of the new conditions some years after the decline in mortality had set in). It is also possible that the decline in fertility may have acted as a powerful force to reduce mortality, as longer gaps between children enabled parents to attend to each child better.

It is essential for demographers to gain a deeper understanding of the mechanisms by which historical changes in mortality affected fertility levels. The study reported in this paper was designed to address precisely this question. My hypothesis was, as the theory of the demographic transition postulated, that mortality was indeed a factor of note that influenced fertility change. I believe that the researchers working on the PEFP were unable to identify this causal relationship because they used the infant mortality rate (a measure of survival to twelve months) as the only general indicator of mortality within populations. By widening my analysis to take in survival to age 25, I considered that it would be easier to show any significant connection with subsequent developments in fertility.

**Sources and methods**

Most of the data on fertility and nuptiality were obtained from the Princeton indices calculated by the PEFP for different provinces within Europe (Coale and Treadway 1986). The Princeton indices are: the overall fertility index ($I_p$), the marital fertility index ($I_m$), the extra-marital fertility index ($I_b$), and the nuptiality index ($I_n$). For further details of these, see Coale and Treadway 1986. I also made a great effort to fill in gaps in data, using information that was not available at that time. I was only able to obtain data for the Princeton indices at the provincial level for European countries, because they benefited from the oldest and most reliable historical sources (censuses and vital statistics) for calculating fertility, nuptiality, and mortality indicators. On a national level, however, I made the effort to calculate the Princeton indices and the mortality indicator $25d_0$ (probability of dying before age 25) for some non-European countries: Australia, Canada, Japan, New Zealand, and the United States (see Figure A1 in the supplementary material). All the details concerning the sources consulted and the calculations carried out are specified in the supplementary material.

Coale and Treadway (1986, pp. 156–62), who designed the Princeton indices, admitted that they were influenced by the age structure of the female population. This causes a problem when comparing the values for populations with different age distributions. Knoedel (1978), Guinnane et al. (1994), and Brown and Guinnane (2007) demonstrated that the marital fertility index ($I_m$) cannot be used with any reliability to date the initial stages of the transition or to detect how birth control came into use. Also, when comparing regions and periods characterized by enormous variations in age patterns of marriage, and marital dissolution, it is
important to be aware of the inherent shortcomings of the Coale indices. It has been demonstrated, for example, by Caldwell et al. (1982) and Burch and Ashok (1986), that these variations can lead to noticeable differences in the standardized indices without there being large differences in the inherent fertility patterns.

Some researchers (Reher 1999; Guinnane and Brown 2002; Brown and Guinnane 2003; Reher and Sanz-Gimeno 2007; Van Poppel et al. 2012) have expressed considerable scepticism as to the usefulness of aggregated data for understanding historical changes in reproductive behaviours, and have recommended using information about individual cases obtained through family reconstruction techniques. Individual-level data might yield more nuanced results that would help fit the theory better, but, unfortunately, they cannot cover such a broad geographical area or such a long time frame. Many studies that have set out to explain the demographic transition have focused on the experience of a single country. The information presented is often partial and only reflects one small part of the transition. This is a major limitation when it comes to building a general explanation that can account for the process of demographic transition.

Despite the limitations concerning both the data gathered and the indices developed by the Princeton project, I made use of this information because it was the most comprehensive database to include demographic data for all European provinces (almost 600) over a period of more than 150 years. Aggregated data enabled me to amass a data set for a considerable number of countries and provinces, far beyond what would be possible with microdata. As I explain later, my results differed greatly from those obtained by the PEFP, although I used data from the same source, doubtless because of the different methods and focus used.

As far as mortality is concerned, some experts (Reher 1999) consider that one of the main shortcomings of the PEFP was that it used the infant mortality rate as the sole indicator of the intensity of mortality. At the very least, only taking account of the deaths of children aged less than one year could be deemed somewhat reckless, since this figure cannot possibly tell us much about the whole story. Wrigley (1969) and Matthiessen and McCann (1978) indicated that, in most European countries, the mortality rate among children aged 1–14 years fell long before the infant mortality rate. In short, there is a sizeable group of researchers who consider that it is impossible to assess the effect of mortality on the drop in fertility by only taking infant mortality into account.

I obtained both the infant mortality rate and the probability of dying before the age of 25 ($z_{25}$) for each province, in order to compare the differences when each of these mortality indicators was used. I chose the age of 25 because I felt that survival to that age would serve as a good indicator of couples’ perceptions concerning the mortality patterns they would face when taking decisions on reproductive issues. Calculating the probability of dying in the first 25 years of life ($z_{25}$) in each province and for each census year was not feasible for the Princeton study. However, since this project published its conclusions, several demographers have undertaken the colossal task of calculating life tables for the provinces of various countries (France, Spain, Portugal, the Netherlands, Germany, and Canada) for certain periods of time. In addition to using provincial life tables calculated by other authors, I had to compile the information needed to calculate approximately 5,500 life tables for different provinces within Europe.

The following list sets out the countries for which I gathered data for provinces and calculated the probability of dying before age 25 (in parentheses I show the time period and the number of time points within each period for which I was able to obtain information):

- France (1831–2000; 22 time points measured during this period): 90 départements
- England and Wales (1850–1950; 8): 45 counties (I put the counties of Wales together into two groups: North Wales and South Wales)
- Spain (1863–2001; 13): 50 provinces
- Italy (1871–2001; 13): 19 regions
- Portugal (1913–81; 9): 22 districts
- The Netherlands (1860–1960; 3): 11 provinces
- Sweden (1861–1971; 5): 25 provinces
- Germany (1875–1925; 9): 4 Länder (because of the small number of administrative areas for which I was able to obtain life tables, readers should exercise caution when interpreting correlation coefficients using the variable $z_{25}$ in this case)
- Canada (1921–2009; 88): 12 provinces.

Although I was unable to calculate life tables for the provinces of Belgium, Switzerland, and Denmark, I used their infant mortality rates as a lesser evil, bearing in mind at all times the limitations of using this measure. I considered that its use might enrich this study in that it enabled me to increase the number of countries from which provincial information was available, as shown in the following list:
- Belgium (1846–1970; 12 time points): 9 provinces
- Switzerland (1870–1960; 10): 25 cantons
- Denmark (1852–1940; 7): 22 provinces.

Once the data for overall fertility ($t_0$), marital fertility ($t_2$), nuptiality ($t_m$), and mortality ($m_0$ and infant mortality rate (IMR)) had been gathered for each province, the method used in my analysis was quite straightforward: I calculated the correlation coefficients between these variables and observed how they evolved over time.

Since the correlation coefficients varied according to the stage they are from within the demographic transition, I thought it would be important to mark the moment at which this transition began and ended in each country. If, as I assumed, mortality is the key factor that conditions fertility levels, it would be important to establish when mortality started to fall. The two vertical dashed lines in Figures 1, 2, and 4 (shown later) separate the three phases of the transition in mortality: the pre-transitional stage, the transitional stage, and the post-transitional stage. The year when the mortality transition began was established for each country at the point when the mortality rates ($m_0$) began to fall definitively, that is, when a clear downward trend became established and mortality never subsequently returned to levels previous to the initial fall. In the cases of England and Wales, Denmark, and Sweden, I had some difficulty determining the moment at which the demographic transition began. In these three countries, there were perceptible falls in mortality from the second half of the eighteenth century onwards, but they were not definitive, unlike the decline at the end of the nineteenth century (see the supplementary material for further information). It is very likely that couples did not perceive this initial decline as permanent, and so for these three countries I decided to set the start of the transition at the end of the nineteenth century. However, in the relevant figures I include a third dotted line indicating that the transition may have started earlier (see the supplementary material for more detailed information on this). In the case of countries where there were no $m_0$ values far enough back in time to capture the precise moment at which the decline in mortality occurred, I established the year of onset of the transition by referring to information provided by other demographers. I established the end of the mortality transition arbitrarily as the year when a given country reached a $m_0$ value equal to 0.05 (i.e., when only 5 per cent of people died before the age of 25).

In each of the figures, I try to include the maximum number of countries. Readers may note that the countries included vary between figures; this is simply because information was not available for all the countries and categories. Many of the figures show trends in the correlation coefficients of two different variables, hence where information about one of these variables was absent, the country could not be included. For example, I obtained life tables for the provinces of Canada, but were unable to gather the data needed for the Princeton indices. This means that Canada does not appear in Figures 1 and 2, but does appear in Figure 4.

The correlations between the different Princeton indices of fertility

Before embarking on a detailed analysis of the synergies between mortality and fertility, I needed to ascertain how the different Princeton indices related to each other in the three major phases of the demographic transition. Until a few decades ago, the overwhelming majority of births in Europe took place within marriage. In these circumstances, the overall fertility index ($t_0$) logically depends on two variables: the intensity of marital fertility ($t_2$) (i.e., how many children married women had) and the intensity of nuptiality among females ($t_m$) (i.e., how many women married and at what age). For practical reasons, my analysis did not take account of the intensity of extra-marital fertility ($t_e$), which was very low in Europe until a few decades ago. Figure 1 shows how the correlation coefficients between these three indices have changed over time. This figure includes a selection of countries included in the database of the PEFP (Coale and Treadway 1986).

Historically, the different demographic variables (mortality, fertility, nuptiality, and migratory flows) were intrinsically interrelated and maintained a certain balance. Fertility was strongly conditioned by the intensity of mortality, and was also affected by the percentage of young people who got married. Similarly, access to marriage depended not only on the resources in the geographical environment, but also on life expectancy. Neither the values nor the trends in each of these variables can be understood in isolation from the others and the harmonious associations between the variables could be ruptured if one of them changed dramatically. In what follows, I analyse the historical evolution of the relationships between some pairs of variables, and observe how the fall in mortality affected these relationships.
During the decades of the transition in mortality, the positive relationship between overall fertility ($I_d$) and marital fertility ($I_m$) generally became stronger. Except in the case of Germany, all the countries displayed a clear tendency for the correlation coefficients between these two variables to rise. In Switzerland, the Netherlands, Portugal, Spain, and England and Wales, the relevant correlation coefficients went from around 0.4 at the start of the transition to around 0.9 by the end. That is, in the peri-transitional stage (defined as the period around the onset of the demographic transition), a considerable proportion of variability in overall fertility could not be accounted for by marital fertility. At that time, the regulation of overall fertility through access to marriage was of great importance. At the beginning of the mortality transition, overall fertility ($I_d$) was correlated with the intensity of nuptiality among females ($I_m$), with very high positive values (around 0.8) in many of the countries. That is, provinces with the highest levels of nuptiality were also those with the highest overall fertility values. During the transitional period, this relationship changed sign from positive to negative in some countries (Italy, Portugal, the Netherlands, and Switzerland).

These data indicate that during the transitional period, marital fertility took on a fundamental role in the regulation of the overall fertility index, to the detriment of nuptiality itself. The plummeting of mortality rates resulted not only in a change from high to low fertility, but also led to a Copernican turn in the influence of both marital fertility and nuptiality on overall fertility. There is no doubt that the key factor underlying these radical changes was mortality, as we shall see later in this section.

The relationship between nuptiality ($I_m$) and marital fertility ($I_d$) is the one whose interpretation poses the greatest challenges. In fact, it is a simple task to find a clear pattern in the evolution of the correlation coefficients between these two indices. In some countries, such as France, Belgium, the Netherlands, and even Germany, there is little doubt that in the nineteenth and early twentieth centuries, the départements and provinces with the highest marital fertility were those with the lowest levels of nuptiality.

When, instead of using the indicator of marital fertility as it stands ($I_d$) for the correlation, I used it weighted by the probability of surviving to age 25 to create the net marital fertility index ($I_{d25}$), the result I obtained sheds even more light on the situation. It was useful to perform this weighting because the fact that a greater or lesser percentage of the population has access to marriage depends not so much on the number of children born (many of whom might die in infancy), as on the proportion who survive to adulthood (defined as, for example, age 25). When I correlated $I_{d25}$ with $I_m$ (Figure 1), I found that in France, England and Wales, Spain, the Netherlands, Germany, and to some extent in Italy, the values were negative in the peri-transitional period. That is, the provinces with higher values of $I_{d25}$ were also those where access to marriage was more restricted. Nuptiality in the peri-transitional phase was therefore the decisive factor that regulated overall fertility.

As the transition set in, the negative correlation between $I_{d25}$ and $I_m$ came to depend less on the percentage of children surviving into adulthood, and more on other factors, as we shall see in the next section.

The correlation between marital fertility and mortality

Figure 2 shows how the correlation coefficients between marital fertility ($I_d$) and mortality evolved. The countries shown in this figure are conditioned by the availability of data at the provincial level for the marital fertility indicator and for at least one of the mortality indicators ($I_{d25}$ or IMR).

In the early stages of mortality decline, the correlation coefficients were close to zero. In none of the countries analysed was I able to detect any clear indication that there was a positive correlation between these two variables during this peri-transitional period.

Why is it that there was generally no correlation between mortality and marital fertility during this period? We might take the view that one of the reasons was probably linked to what is known as natural fertility (Henry 1961). Some authors consider that under conditions of natural fertility, we ought not to expect to find a strong relationship between marital fertility and mortality, because fertility ‘is not within the calculus of conscious choice’ (Coale 1973, p. 65). As Van de Walle (1986, p. 203) states: ‘Before contraception appears within marriage, fertility is not something that can be turned on and off at will in function of experienced or expected parental losses.’ My own position is diametrically opposed to these interpretations. I consider that the lack of any correlation between marital fertility and mortality in the peri-transitional era should not be regarded as proof that no conscious control of marital fertility was being exercised.
Figure 1  Continued on the next page
Figure 1  Trends in correlation coefficients between the overall fertility index ($I_o$), nuptiality index ($I_n$), marital fertility index ($I_g$), and net marital fertility index ($I_g \times 25p_0$) at the provincial level, for 14 countries, 1740–2010

Notes: The two vertical dashed lines on each chart separate the three phases of the mortality transition: pre-transitional, transitional, and post-transitional. For England and Wales, Denmark, and Sweden, a third, dotted, line indicates that the transition may have started earlier. See Sources and Methods section for more details. Data for $25q_0$ were not available for Switzerland, Belgium, Denmark, Ireland, Russia, or Hungary. Denmark had 22 provinces, Ireland had 31 counties, and Hungary 73. Depending on the years in question, the number of provinces with data available in Russia ranged from 51 to 81. The correlations for Belgium were performed using the data from the 41 arrondissements.

Source: Data from Coale and Treadway (1986), author’s own calculations, and a range of other sources; see the supplementary material for full details.

In natural fertility contexts, marital fertility levels may have varied owing to factors related to health and nutrition, such as reduced sexual activity in populations subject to chronic diseases, high miscarriage rates in women with anaemia, and sterility caused by venereal diseases or tuberculosis. Poor health can affect the frequency of coitus or lengthen the period of amenorrhoea. On other occasions, marital fertility may have been lowered by the periodic separation of spouses as a result of seasonal migration, or absence from home, on the part of fishermen and shepherds. Another major source of differences in natural fertility was differences in breastfeeding practices, since these influence the onset of menstruation and ovulation after childbirth (Van de Walle 1975; Menken 1979; Konner and Worthman 1980).

All these factors made it impossible, in the context of natural fertility, for couples to increase the number of children they had at will, but the same factors did not in any way stop them from reducing that number (or delaying the birth of the next child until a more convenient time of year). The lack of correlation between marital fertility and mortality in the perit-transitional era can be explained by the fact that many provinces experienced high mortality rates and even if couples wanted to have more children, they were not able to, for the reasons explained earlier, which were beyond their control.

Although in France, Belgium, and the Netherlands we observed positive coefficients between marital fertility and mortality throughout the nineteenth century, this may have been because these countries
Figure 2  Continued on the next page
Figure 2 Patterns in correlation coefficients between the marital fertility index and probability of dying before age 25 ($I_g$ and $25q_0$), and the marital fertility index and infant mortality rate ($I_g$ and IMR), at the provincial level for eleven countries, 1740-2010.

1The correlation coefficients for ‘Sweden B’ were obtained using figures for legitimate births per 1,000 married women, instead of $I_g$.

2For Germany, data were available for only four Länder so readers should exercise caution when interpreting the correlation coefficients for this country.

Notes: The two vertical dashed lines on each chart separate the three phases of the mortality transition: pre-transitional, transitional, and post-transitional. For England and Wales, Denmark, and Sweden, a third, dotted, line indicates that the transition may have started earlier. See Sources and Methods section for more details. Data for $25q_0$ were not available for Switzerland, Belgium, or Denmark.

Source: As for Figure 1.

experienced an earlier mortality transition than the others, that is, these countries were the forerunners (vertical lines in Figure 2 indicate the dates at which the mortality transition began and ended in each country). Whereas in the other European countries analysed, the decline in mortality did not begin until the late nineteenth century, in France it is estimated to have started in the 1780s (Blayo 1975; Meslé and Vallin 1989). The fall in mortality in France was accompanied by a drop in marital fertility, as would be expected. I think it is highly likely that, at the start of the demographic transition in eighteenth-century France, the correlation coefficients between $I_g$ and $25q_0$ were very near zero, as was the case in other European countries. Unfortunately, no data were available for the départements within France for the peri-transitional years (around 1780) and I was not able to correlate mortality with marital fertility for that period. A drop in mortality as early as that in France was neither observed in England and Wales, nor Germany, nor Italy, all countries with several centuries of historical records concerning mortality rates.

A similar pattern to that observed for France was found in the Netherlands, where the correlation coefficient (between $I_g$ and IMR) for 1860 was already positive (0.4) (Figure 2). The data available on mortality for this country suggest that it had been falling since at least 1820 (Rothenbacher 2002). Once again, I found positive correlations between these two variables during the transitional period (but not before).

Belgium also showed the same pattern as France regarding correlation coefficients. In the second half of the nineteenth and during the early twentieth century, the coefficients (between $I_g$ and IMR) were very high, with the expected sign (positive). If, as Devos (2003) indicates, the drop in mortality in Belgium began at the beginning of the nineteenth century, it is possible that the high correlation coefficients detected in the mid-nineteenth century reflected an earlier drop in mortality.

In the conclusions to the PEFP, Van de Walle (1986, p. 228) states:

In sum, we find in Switzerland the kind of textbook case we were looking for: no relationship [between $I_g$ and the infant mortality rate] before the onset of family limitation, a decline of infant mortality that precedes and therefore also possibly causes the decline of marital fertility, and a positive relation that becomes increasingly significant as the decline progresses.
I found the same kind of textbook case, not only for Switzerland, but also most of the other countries analysed (perhaps with the sole exception of Denmark during certain time periods).

During the transitional period, it is evident that the correlations between mortality and marital fertility became stronger. My data appear to suggest that, as the traditional theory of the demographic transition maintains, mortality was a determining factor in the historical decline in marital fertility levels. Some authors using individual data (Reher and Sanz-Gimeno 2007; Van Poppel et al. 2012) have concluded that the increasing strength of the mortality-fertility effect can be explained by an increasing willingness to use fertility limitation coupled with more efficient methods of birth control.

This positive correlation increased for several decades after mortality had fallen, then gradually diminished once the process of transition was complete (post-transitional phase), until it almost disappeared (see, e.g., Spain and Sweden). The weakening of the correlation coefficients between \(I_m\) and \(\frac{\mu_0}{\gamma_0}\) is to be expected since, once mortality indicators fell below a certain level, it is logical that the differences in marital fertility in the different départements, provinces, and countries would have been affected by other factors. Nonetheless, it is important to point out that in some countries (France, Italy, Portugal, and the Netherlands), the correlation coefficients remained steady at around 0.6 until as late as the 1960s, when the mortality rates were very different from those observed at the end of the nineteenth century.

One of my aims was to test the discrepancies that result from using \(\frac{\mu_0}{\gamma_0}\) or the infant mortality rate in my statistical correlations. For certain years, in some countries (France, Portugal, and Germany), I found significant disparities, which means that the infant mortality rate should be used with caution as an indicator of general mortality. Although I found that using the probability of dying before the age of 25 (\(\frac{\mu_0}{\gamma_0}\)) is a useful indicator of the intensity of mortality, where this is not available, the infant mortality rate can serve as a reasonable substitute.

**Did marital fertility ever fall before mortality declined?**

Some researchers have pointed to cases in which the drop in marital fertility predated the decline in mortality (Knoedel 1974, pp. 167–85). These cases pose a genuine challenge to the assumptions underlying the theory of the demographic transition. On the basis of the information gathered, it is not possible to maintain that there was any single country in which marital fertility (\(I_m\)) fell significantly before mortality (\(\frac{\mu_0}{\gamma_0}\)) began to decline (see Figure 3 for selected countries, and Figure A1 in the supplementary material for the remaining countries). Morgado (1979) dates the drop in mortality in Portugal to the late nineteenth century, that is, before marital fertility fell (around 1900). The high variability in mortality rates in Iceland during the second half of the nineteenth century suggests that we should exercise prudence when trying to establish the date at which mortality began to decline there.

The earliest figures available for \(I_m\) and \(\frac{\mu_0}{\gamma_0}\) in many countries are for the last decades of the nineteenth century. During those years, mortality and marital fertility in many of these countries were already both on the decline, that is, the process of transition had already begun. In the countries where high quality data for several hundred years are available (France, England and Wales, Italy, Denmark, Finland, Sweden, and Norway), we can observe that the drop in mortality always preceded the decline in marital fertility.

The demographic transition theory postulates that there is a time lag separating the fall in mortality and the decline in marital fertility, which reflects the time that parents needed to adjust to new conditions. In most of the countries for which I obtained information, marital fertility decreased very swiftly after mortality began to fall (this can be observed particularly clearly in France, England and Wales, Germany, Spain, Italy, the Netherlands, and Finland in Figures 3 and A1). It is also true that in a few cases (particularly in northern European countries such as Denmark, Norway, Sweden, and Ireland), several decades went by with a continuous decline in mortality before marital fertility began to decrease.

Although I failed to find any country in which the drop in marital fertility preceded the decline in mortality, that does not mean that there were no social groups (generally of a minority nature) whose specific economic and social circumstances could have made it rational for them to reduce their marital fertility before the widespread drop in mortality. Livi Bacci (1986) found behaviour of this kind among the aristocracy and in some Jewish communities.

**The correlation between overall fertility and mortality**

Figure 4 shows how the correlation coefficients between the overall fertility rates (\(I_f\)) and mortality rates (\(\frac{\mu_0}{\gamma_0}\) and IMR) evolved over time. In general,
Figure 3 Trends in the marital fertility index ($L_g$) and the probability of dying before age 25 ($z_{0.0}$) in nine countries (five-year moving average), 1740–2010.

1Data for mortality before 1872 are only for the north of Italy.

Note: Figure A1 in the supplementary material provides the same information for a further 16 countries.

Source: As for Figure 1.

we can say that during the peri-transitional stage there was a positive correlation between these two variables, as would be expected: the provinces with the highest mortality rates were also those with the highest overall fertility rates. Historically, the correlation coefficients between these two variables were moderately high and in the expected direction (positive), in accord with the premises underlying the theory of the demographic transition, which take mortality to be the main factor that regulates fertility rates. Once the transition had begun, it is even possible to detect an increase in the correlation coefficients (England and Wales, Italy, Portugal, and Sweden), which seems to indicate that at this stage, the regulatory role of mortality with respect to overall fertility was reinforced.
Figure 4  Trends in correlation coefficients between the overall fertility index and probability of dying before age 25 (‘$I_f$ and z$\sigma$0’), and the overall fertility index and infant mortality rate (‘$I_f$ and IMR’), at the provincial level, for nine countries, 1740–2010.

The correlation coefficients for ‘Sweden B’ and Canada were obtained using the total fertility rate instead of $I_f$.

For Germany, data were available for only four Länder so readers should exercise caution when interpreting the correlation coefficients for this country.

Notes: The two vertical dashed lines on each chart separate the three phases of the mortality transition: pre-transitional, transitional, and post-transitional. For England and Wales, Denmark, and Sweden, a third, dotted, line indicates that the transition may have started earlier. See Sources and Methods section for more details. Data for z$\sigma$0 were not available for Switzerland, Belgium, or Denmark.

Source: As for Figure 1.
In some countries, at the start of the transition, the correlation coefficients between $I_r$ and $z_{90}$ were only moderately positive (around $0.4$), which indicates that an important proportion of the variability in overall fertility could be attributed to factors other than the mortality rate (England and Wales, Italy, and Portugal). Sweden is worthy of special attention. In spite of the improvements in mortality rates observed over the nineteenth century, the correlation coefficients between overall fertility (TFR or $I_r$) and mortality ($z_{90}$ and IMR) were negative between 1860 and 1880, which clearly contradicts the assumptions underlying the theory of the demographic transition. Further research is needed in order to understand this singularity, and it will also be necessary to go into greater depth concerning the role played by marriage rates (and their relationship with mortality rates). Nonetheless, when mortality fell dramatically in Sweden in the late nineteenth century, the correlation coefficients between the two variables started to grow considerably in the expected (positive) direction, reaching very high values.

From what we can see in Figure 4, I believe that mortality played a major (and increasingly important) role in determining the overall fertility rates of the provinces within Europe throughout the years of the mortality transition. Once mortality rates had fallen considerably, it would be logical to suppose that their explanatory capacity with regard to fertility would also fall. As expected, in the post-transitional phase the correlation coefficients generally seem to have been on the decline (e.g., in France, Spain, and Sweden). In a few countries, such as Italy and Canada however, they remained high until very recent times, even though mortality rates had already fallen to low levels.

**What was the role of mortality in the peri-transitional phase?**

In a previous section, we saw that during the peri-transitional phase there was no correlation between the rates of marital fertility and mortality. Does this mean that during this period the mortality rate played no role at all in the fertility patterns that were established within the different areas studied? In the first place, the fact that there was no correlation between mortality and marital fertility clearly does not mean that marital fertility was not generally high during this period of high mortality (in fact, the overwhelming majority of provinces exhibited high marital fertility). The lack of correlation between $I_r$ and $z_{90}$ only indicates that, in this situation of high marital fertility and high mortality, the interprovincial differences in the levels of the former variable were not conditioned by the latter. That is, the lack of correlation between mortality and marital fertility does not necessarily mean that the paradigm underlying the model of the demographic transition was not in operation.

Second, as we saw in Figure 4, overall fertility ($I_r$) did correlate positively with mortality ($z_{90}$) in the early years of the transition. If overall fertility ($I_r$) depended on marital fertility ($I_8$) and nuptiality ($I_n$), and since we have seen that marital fertility ($I_8$) did not correlate with mortality ($z_{90}$), we should conclude that the positive correlation between overall fertility ($I_r$) and mortality ($z_{90}$) was a result of the correlation between nuptiality ($I_n$) and mortality ($z_{90}$). To test this deduction, I combined the data from England and Wales, Spain, and Italy, because data from their provinces were available for the time when the transitional stage began. Using provincial data from these three countries, I calculated the linear regression and correlation coefficients specified in Table 1 (with $I_r$ as the dependent variable in the linear regression) for three points in time: 1886 (when the transition had just started or was on the point of doing so), 1921 (some decades into the transition), and 1961 (when the transition was complete, or nearly complete).

Table 1 shows that in 1886, overall fertility ($I_r$) basically depended on nuptiality ($I_n$) (because the standardized regression coefficient of the $I_n$ indicator is notably higher than the $I_8$ indicator). That is, the differences in overall fertility levels between the different provinces were mainly determined by the differences in the intensity of nuptiality. In this peri-transitional period, nuptiality (much more than marital fertility) was what regulated overall fertility. We can infer from the linear regression set out in Table 1 that as time passed, and the demographic transition got into full swing, the influence of nuptiality on overall fertility gradually waned (as discussed with reference to other countries in the comments on Figure 1).

On the other hand, marital fertility took on greater importance. The correlation coefficients between $I_8$ and $z_{90}$ thus increased while those of $I_n$ and $z_{90}$ decreased. In fact, by the end of the demographic transition, both correlations actually changed sign. Why did the correlation coefficients between $I_n$ and $z_{90}$ change from positive to negative? It is natural that, in the peri-transitional phase (with high mortality), provinces with the highest death rates would experience higher nuptiality. The maintenance of the population was somehow ensured by making sure that young people had access to marriage (and
Table 1  Linear regression (with \( I_t \) as the dependent variable) and correlation coefficients between indices for the provinces of England and Wales, Spain, and Italy combined, 1886, 1921, and 1961

<table>
<thead>
<tr>
<th></th>
<th>Circa year 1886</th>
<th>Circa year 1921</th>
<th>Circa year 1961</th>
</tr>
</thead>
<tbody>
<tr>
<td>( I_t )</td>
<td>Coefficient</td>
<td>Beta</td>
<td>Coefficient</td>
</tr>
<tr>
<td>( I_t )</td>
<td>0.480*</td>
<td>0.435</td>
<td>0.505*</td>
</tr>
<tr>
<td>( I_m )</td>
<td>0.620*</td>
<td>0.908</td>
<td>0.562*</td>
</tr>
<tr>
<td>Constant</td>
<td>-0.276*</td>
<td></td>
<td>-0.269*</td>
</tr>
<tr>
<td>( R \text{-squared} )</td>
<td>0.940</td>
<td></td>
<td>0.990</td>
</tr>
<tr>
<td>( RMSE )</td>
<td>0.130</td>
<td></td>
<td>0.010</td>
</tr>
</tbody>
</table>

Notes: \( I_t \) is the overall fertility index, \( I_m \) is the marital fertility index, \( I_n \) is the nuptiality index, and \( 25q_0 \) is the probability of dying before age 25. Significance levels: * 1%.

Source: Author's own calculations using data from a range of sources; see supplementary material for full details.

therefore reproduction) in places where mortality was high. Once the transition was over and mortality no longer played a leading role, access to marriage was conditioned by other indicators (e.g., the availability of employment which would enable young people to set up home).

Mortality therefore had an indisputable role in determining the different levels of overall fertility at the provincial level: in the peri-transitional period, mortality exerted its effects through the influence it had on nuptiality, while in the transitional period, mortality was important because of its impact on marital fertility.

Conclusions

I believe that the results of this study justify the considerable efforts made to gather the information in order to obtain as detailed an overview as possible of the demographic transition in 25 countries over a lengthy period of time. My study was based on both published data and my own calculations using information collected laboriously from primary sources. Although some researchers have expressed their scepticism about the utility of aggregated data, I have shown that it is beneficial to use information for provinces.

The conclusions of my research suggest that both before and during the transitional period, mortality played a fundamental role in conditioning historical fertility levels (this statement does not rule out the possibility that there were also other factors that might have had some bearing on the fall in fertility). My data would seem to confirm the main paradigm of the classic demographic transition theory that was questioned by the PEFP. I was able to show that in the peri-transitional period, mortality conditioned overall fertility by way of nuptiality (the provinces with higher levels of mortality were those that experienced the highest nuptiality). Once the transitional period had begun, the effects of mortality on marital fertility were strengthened, and its relationship with nuptiality was weakened, but the result was the same: mortality was still the explanatory key to overall fertility patterns. I also showed that all the countries analysed followed a similar pattern of change. In all of them, the fall in mortality preceded that of fertility, although I also found significant differences in the time lapse between the two events. The most noteworthy divergences between countries were only marked by the differences between the forerunners and laggards in the mortality transition.

Nonetheless, my evidence, while highly suggestive that mortality decline plays a key role in fertility decline, falls short of proving causation.

Notes

1 Jesús J. Sánchez-Barricarte is at the Department of Social Analysis, Carlos III University of Madrid, Calle Madrid, 126, 28003 Getafe (Madrid), Spain. E-mail: jesujsjavier.sanchez@uc3m.es

2 Funding: this work was supported by the Spanish Ministry of Economy and Competitiveness of Spain under Grant CSO2012-31206; and Autonomous Community of Madrid under Grant H2015/HUM-3321.
3 The author would like to express his gratitude for the helpful comments made by Professors Antonio Moreno-Almáreagui and Juan M. Franco-Amatrain on a previous version of this paper and for the well-informed contributions by the three anonymous referees who helped improve this paper considerably.

References

Blayo, Y. 1975. La mortalité en France de 1740 à 1829 [The mortality in France from 1740 to 1829], Population Special Number 30: 123–142.


Reher, D. and A. Sanz-Gimeno. 2007. Rethinking historical reproductive change: insights from longitudinal data for


