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Dynamic analysis of the long-term relationships between mortality and marital fertility in the developed world

Jesús J. Sánchez-Barricarte, Ph. D.

Department of Social Analysis

Carlos III University of Madrid

jesusjavier.sanchez@uc3m.es

http://portal.uc3m.es/portal/page/portal/dpto_anal_soc/nuevas/QuienesSomos/Jesus_Sanchez_Barricarte

Luis F. García-Espinal

Carlos III University of Madrid

lgarciaespinal@gmail.com

Biographical Note: Jesús J. Sánchez-Barricarte received his Ph. D from the Department of Demography at the University of California at Berkeley (USA). He is currently professor of Demography at Carlos III University of Madrid (Spain). His research focuses on historical demography, migration, population growth, and population issues in China. He has published several articles in different international journals: Population Studies, European Journal of Population, Biosocial Science,

Annales de Démographie Historique, Asian Population Studies, Continuity and Change, etc.

Luis F. García-Espinal has a BA in Political Sciences and a Master's Degree in *Economic Development and Growth* (Carlos III University of Madrid). He works as quantitative research specialist on behavioral change and development in Sub-Saharan African countries, with extensive experience in data analysis and applied econometrics. His research focuses on behavioral change by intra-household resource allocation and demographic issues by using Time-Series-Cross-Section, panel data and Time-series econometric methods.

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Abstract

According to the traditional theory of the demographic transition, the drop in mortality was the main mechanism which accounted for the subsequent decline in fertility. This basic idea was questioned by the results of the well-known Princeton European Fertility Project, but even now there is relatively little empirical research providing solid evidence that can shed light on the determinants of fertility in modern times. We examine the long-term relationship between marital fertility, mortality, and gross domestic product per capita (GDPpc) using panel cointegration techniques for a group of 15 developed countries from the 19th century until the present day. The statistical models used show that mortality plays a major role in fertility reductions.

Key words

Demographic transition, fertility, mortality, historical demography, European Fertility Project, panel cointegration

1- Introduction

It is generally believed that before the demographic transition, decisions about having children were socially determined (basically through control exercised over access to marriage). Once the transition had begun, social norms gave way to individual or family decisions (Mason, 1997; Reher, 2011). The mortality rate has traditionally been seen as a decisive factor affecting reproductive decisions, but this apparently logical relationship is no more than a theoretical proposition. Coale (1986) believed that a drop in mortality was a necessary condition for a lasting decline in marital fertility. However, the empirical studies associated with the Princeton European Fertility Project (PEFP) were those which raised the most serious questions concerning the idea that, as the theory of the demographic transition proposes, the decline in fertility was a response to an earlier decrease in mortality rates. One of the main conclusions set forth at the end of the PEFP was expressed thus: "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: 233). Many other researchers have reached the same conclusions (Watkins, 1986: 436; Knodel, 1974: 167-185; Lesthaeghe, 1977: 171-176; Teitelbaum, 1984; Haines, 1998). In a study on the state of the question concerning the transition and the theory of fertility, van de Kaa (1996: 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". In his review, Kirk (1996: 368) attempted to show the diverse approaches to causation: socio-economic, economic, institutional, cultural and ideational concluding: "It is perhaps surprising that while mortality decline is usually cited as the *raison d'étre* [reason for being] for fertility decline, it is not often accorded a primary place as a *cause* of fertility decline. This is understandable, since efforts to establish a direct close connection have had mixed results. Whilst definitive proof of this connection may not be possible, there exist cogent reasons for supposing that it exists."

In recent years, studies using longitudinal microdata have made important contributions towards clarifying the relationship between mortality and fertility during the demographic transition (Bengtsson and Dribe, 2006; Knodel, 1988; Wrigley et al., 1997; Van Bavel, 2003 and 2004; Van Bavel and Kok, 2010; Reher and Sanz-Gimeno, 2007; Reher and Sandström, 2015; Van Poppel et al., 2012; Schellekens and van Poppel, 2012; Reher et al., 2017)[1]. These studies show that couples continually regulated their fertility, and that those who had lost a child were significantly more likely to face the hazard of an additional births. Reher et al. (2017: 18) consider that the view that the mortality played a major role in the decline in fertility went from being a cornerstone of demographic transition theory to being considered almost anecdotal as a result of the use of inadequate data because "the only way to show how mortality affected reproduction was by means of linked micro data". However, family reconstruction techniques which provide micro data that can be used to carry out longitudinal studies also have their limitations. First, it is practically impossible to apply them to long periods of time and large geographical areas. In the best case, micro studies can analyze the reproductive behavior of a few thousand couples. The doubt therefore arises as to whether the information that is obtained for a small set of villages is representative of the whole country. It is very hard to build general theories about the decline in fertility on the basis of patterns observed in a small number of towns. Moreover, the differences in reproductive behaviour between rural and urban areas cannot be ignored. In other words, the rich data provided by longitudinal micro studies has to be complemented by other studies based on aggregated data covering much larger areas and longer time periods.

One of the aims of this study is precisely to try to show the historical relationship that has existed between decreases in mortality and fertility by making use of

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[1] Some studies using aggregated data also found a strong association between child mortality and fertility rates (Galloway et al., 1998).

aggregated data for a set of 15 countries[2] using modern econometrics. Arguably, this ranks among the more important questions in Social Science as a whole, not simply in demography.

Historical studies in the context of the PEFP did not use panel data techniques. Brown and Guinnane (2007) point out that when this statistical method is used the role of socioeconomic factors (including mortality and gross domestic product per capita) is restored. Recently, several studies have been published in which panel data techniques are used to analyze the relationship between mortality and fertility over long periods of time and in a wide range of countries. Ángeles (2010) analyzes 118 countries in the period 1960-2005; Herzer et al. (2012) focuses on 20 countries over the 20th century, and Murtin (2013), covers 70 countries from 1870 to 2000. Their conclusions concur that mortality rates do indeed function as a statistically significant predictor of fertility rates throughout history. However, these studies are based on a series of demographic indicators which may be problematic. First, they use as their fertility indicators the crude birth rate (CBR) (Herzer et al., 2012; Murtin, 2013) and the total fertility rate (Ángeles, 2010). It is well known that, in the western world, the vast majority of children have generally been born within marriage, and so nuptiality is also a key factor

[2] In this study we shall focus exclusively on analyzing aggregated data on a national level, but we have also applied the same econometric techniques to provincial data from several European countries. Although some researchers have suggested that aggregated data from countries as a whole conceal the wide variation present in each country (Brown and Guinnane, 2007), we can reveal that the results obtained using provincial information are similar to those from national studies, that is, the level of aggregation of the data does not alter the historical relationship between mortality and fertility (the results obtained using data from provinces will be presented in our forthcoming publications).

in regulating the total number of births that take place. It was only in the 1980s that the percentage of illegitimate births began to rise considerably. That is, historically speaking, fertility rates depended not only on how many children married women had, but also on what percentage of women actually got married. In other words, in developed countries a rise in births was caused by an increase in nuptiality: the influence of nuptiality on total fertility was considerable. If we want to neutralize the possible influence of nuptiality in order to analyze the relationship between mortality and fertility alone, we need to confine our analysis to the impact of mortality on the rates of marital fertility.

Second, the indicators used in this earlier research to measure the general intensity of mortality, such as the crude death rate (CDR), are not refined. Both the CDR and the CBR are heavily affected by the age structure of the population, and their use is not advisable for analyzing lengthy periods of time over which the age structure undergoes substantial changes, as was the case in western countries over the 20th century. Equally, it is not recommended to use them when comparing countries with different demographic structures.

Furthermore, some of these studies also rely on values such as infant mortality and child mortality rates as the only indicators of mortality in the general population. Some experts (Reher, 1999) consider that this was one of the main shortcomings of the PEFP. At the very least, only taking account of the deaths of children aged less than one year might be thought to be somewhat reckless, since this figure cannot possibly tell us much about the whole story[3]. Matthiessen and McCann (1978) and Wrigley (1969) indicated that in most European countries, the mortality rate among children aged 1 to 14 years fell long before the infant mortality rate.

According to Reher et al. (2017: 6), one of the mechanisms through which mortality influences fertility is related to the couple's family size preference[4]. Parents' main aim as far as reproduction is concerned is to reach a number of surviving children rather than a number of children ever born. In the short-term there is a replacement effect (where parents have more births in order to compensate for losing children). In the long-term, "if couples had fertility goals and the ability to implement them, their fertility decisions would tend to be based on the overall survival status of their sibset rather than solely on the outcome of the previous birth".

[3] Very probably the reason why the PEFP researchers used the infant mortality rate as the indicator for the general mortality rate is that it is easy to calculate, and it is relatively simple to obtain the historical information needed to work it out. But now we have historical life tables for a large number of western countries (and even for many of the provinces within them) which give use much richer and more reliable data about general mortality patterns. For this reason, we consider that it is more appropriate to use this method.

[4] There are another two mechanisms which might explain the influence of the decline in mortality on the historical decrease in fertility. One of these has a biological basis: the death of a baby who is breastfeeding means that the infertile postpartum period comes to an end (Knodel and van de Walle, 1967). The third mechanism operates at community level: the decrease in child and youth mortality may transform the unwritten rules within the community, and change people's reproductive behavior. For example, institutional structures (such as the systems 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).

We consider that an indicator that reflects more accurately the long-term behavioral responses to childhood mortality is $_{25}q_0$ (that is, the likelihood of dying in the first 25 years of life). The survival to this age could be a good indicator of the way couples perceived the long-term patterns of mortality around them when they took decisions concerning reproduction. Parents' decisions about the number of children to have basically depend on the mortality rates present during the first decades of life in the social environment where they live. Further, it is very likely that the adjustment that parents make in terms of fertility will depend on the mortality rates observed not when they actually have their children, but during the years prior to that. For this reason, we should expect a relationship between the fertility level in a particular year and the mortality level observed 5-10 years previously. It takes several years for people to adjust to the idea that the change in mortality is permanent, not merely due to chance, and it is a common feature of the demographic transition in western countries that the drop in mortality precedes the decline in fertility by several years.

Some researchers have pointed out that when fertility rates are very high, the relationship between childhood mortality and fertility can be two-way. Children in large families may suffer from higher mortality, because their mothers have less time to take care of them (Oris et al., 2004; Knodel, 1988; Van de Kaa, 1996). However, recent studies based on micro data do not support the hypothesis that fertility transitions influence the decrease in infant mortality (Fernihough and McGovern, 2014).

Our aim in this study is to know how mortality affects marital fertility in the long-term, controlling for other potential determinants discussed in the literature, using more reliable mortality indices, and making use of modern econometric techniques.

2- Data

For the purposes of this study, we collected information on the marital fertility and mortality in 15 developed countries over a very long period of time (in some cases, from the early decades of the 19th century until 2008). The fertility indicator we used was that known as the Princeton index of marital fertility I_g. This index is widely used in historical studies, and consists of the ratio of the number of births occurring among married women to the number that would occur if married women were subject to maximum fertility (married Hutterite women)[5]. Most of the data on marital fertility was obtained from Coale and Watkins (1986). This data is also available from the following University of Princeton website: http://opr.princeton.edu/archive/pefp/. Despite the fact that this index presents certain limitations (Caldwell et al., 1982; Burch and Ashok, 1986; Brown and Guinnane, 2007), we made use of this information because it is the most comprehensive database including statistics for all European countries and provinces over a period of more than 100 years. The values of I_g were calculated for the census years. We used a simple linear interpolation to fill in the gaps for the years between censuses[6]. The appendix provides details of the many sources that we consulted in order to gather the information for each of the countries in the study.

Regarding the mortality index ${}_{25}q_0$, in the appendix we also list the large number of sources we had to consult in order to complete the information for the group of countries in our study. We have included the largest number of countries for which we

[5] See Coale and Watkins (1986: 153-162) for information on how this index is calculated.

[6] We did not carry out this interpolation in cases where more than 11 years elapsed between censuses.

were able to find historical data of proven reliability from (at least) the end of the 19th century up to the present day: Belgium, Denmark, England and Wales, Finland, France, Germany, Italy, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland and the United States of America.

We also made a great effort to fill in the gaps in the information that was not yet available. For example, we calculated the Princeton marital fertility index for some non-European countries like New Zealand and the United States. We also obtained various kinds of socio-economic information (GDP per capita) needed to apply the statistical models specified below. All the details concerning the sources that we consulted and the calculations that we carried out are specified in the appendix.

All the statistical analyses in this study are based on aggregated data from specific countries, even though some scholars (Guinnane and Brown, 2002; Reher and Sanz-Gimeno, 2007; Brown and Guinnane, 2007; van Poppel et al., 2012) have expressed great skepticism as to the usefulness of aggregated data for understanding changes in reproductive behaviors in the past.

3- Methodology

When time series are used to measure the relationship between two trending variables one often obtains spurious regression results. Often detrending helps to eliminate these, but this technique does not work either when the variables are difference-stationary, also labeled I(1). Tests of cointegration can be used to test whether the relationship between two I(1) variables is true or spurious (Engelhardt et al., 2001: 11-12).

Recently a series of studies was published which apply modern panel cointegration tecniques like Vector Error Correction Model (VECM), Dynamic Ordinary Least Squares (DOLS) and Fully Modified Ordinary Least Squares (FMOLS) to analyze the relationship between different sociodemographic variables in the long term (Hondroyiannis and Papapetrou, 2002 and 2005; Narayan and Peng, 2006; Hondroyiannis, 2010; Ángeles, 2010; Frini and Muller, 2012; Herzer et al., 2012; Hafner and Mayer-Foulkes, 2013; Murtin, 2013; Bakar et al., 2014; Hartani et al., 2015).

VEC models are a development on VAR models (vector autoregression) (Engle and Granger, 1987). When two variables of interest are endogenous, they develop a divergent or convergent trend in the long term. These models have been perfected in the area of economics, in order to address issues such as the relationship between different variables such as, for example, inflation, interest rates and unemployment. These economic variables are found to have an endogenous relationship and feed back onto each other. In this case, a VAR model can be used if the variables are stationary. However, we could be interested in analyzing the long-term equilibrium of the two variables (as long as they are all of the first order of integration), rather than the short-term equilibrium, because this could be subject to distortions. In this research, we are interested in observing the long-term relationship between variables I_g and ${}_{25}q_0$ (which are integrated in order 1), and our hypothesis is that these will have a positive relationship, following a similar trend. This tendency to develop together is known as cointegration. Once these relationships of cointegration have been found, we intend to show the sign of this relationship, since this will tell us whether the relationship is convergent (positive, where both variables have the same trend) or divergent (negative, where the course taken by one variable diverges from that of the other). On the other hand, this kind of model also allows us to observe the relationship of one of the variables when the other is exposed to a shock or an innovation (a short-term change or increase). These reactions are known as Impulse/Response functions (and are shown in Graph A4 in the Appendix, in order to provide further details about our results).

On the other hand, to show that the trend is homogeneous for the different countries, we also implemented the FMOLS and DOLS models (Saikkonen, 1992; Phillips and Hansen, 1990). While these have the same purpose as the VECM model (the main aim is to observe the relationships and trends for two variables in the long term), the FMOLS models modify OLS methodology (which is non-parametric[7]) to take into account the negative effects of serial correlation and endogeneity as a product of cointegration relations. We also incorporated the DOLS models (a parametric method) for the panel data, which, though dealing with similar problems, introduce lags and leads to solve issues related to the order of integration and the existence (or not) of cointegration, and are computationally more efficient.

Panel studies offer many advantages over time series and cross-section analysis. Having data from a large number of years increases the sample size and may lead to more reliable estimates. Also, having multiple observations for each country enables researchers to include country-specific fixed effects, thereby controlling for a wide range of time-invariant country characteristics whose omission might otherwise bias the

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[7] The DOLS method is a parametric approach to correct autocorrelation by adding leads and lags as the first difference. By contrast, FMOLS is a non-parametric approach to autocorrelation correction, but this method is quite biased in small estimator results. In this regard, DOLS method can be used in cases with small samples. FMOLS uses a parametric approach, not OLS, as the standard methodology.

estimated relationship between the variables (Hondroyiannis and Papapetrou, 2005: 145).

We were able to use our data to perform an analysis of time series for 15 countries and to model the long-term relationship between the relevant variables (I_g and ${}_{25}q_0$).

4- Cointegration equation by country

The analysis of the time series was performed in the field of econometrics because of the benefits of using vector error correction (VEC) when the variables are endogenous. The advantages stem from the fact that the calculation is performed using a system of equations in which each variable is dependent and independent in turn, so that we can avoid the circularity resulting from using endogenous variables. This approach helps us to model short- and long-term patterns and incorporate tests of causality.

In Table A1 in the Appendix we present detailed descriptive statistics of the datasets involved and Graphs A1 to A5, also in the Appendix, may be helpful to readers for graphical examination of the long-run trends in the variables of interest.

In order to model our hypothesis (that the drop in mortality caused the subsequent decline in marital fertility), we followed the steps set out below:

- Checking structural breaks in our dependent variable of interest (I_g). These tests were carried out in those countries that present a positive sign in the correction term error. As we shall see, only England and Wales, and Sweden, still have a positive sign, which means that some other demographic dynamics may be being ignored in our models.

- Testing for unit root by Augmented Dickey-Fuller test (ADF) (Dickey and Fuller, 1979), Phillip-Perron test (PP) (Phillips and Perron, 1988) and Kwiatkowski-Phillips-Schmidt-Shin test (KPSS) (Kwiatkowski et al., 1992) and taking differences when necessary.

- Computing VAR models to outline the short run and obtain the proper lag length.

- Testing for cointegration equations by using the information about ADF, PP and KPSS as well as lag length from VAR.

- Computing VECM using the information from the Johansen-cointegration test (Johansen and Juselius, 1990; Johansen, 1991 and 1995).

The formal expression of the model is as follows:

$$\Delta\Pi_t = \theta\beta'\Pi_{t-1} + \sum_{j=1}^{k} \alpha\Delta\Pi_{t-j} + e_t \qquad (1)$$

Where Π_t is the set of endogenous variables I_g, ${}_{25}q_0$ and gross domestic product per capita (GDPpc)[8] at time *t,* $\theta\beta'\Pi_{t-1}$ is the expression that determines the long-term relationship, $\Delta\Pi_{t-j}$ is the short-term and e_t is the error term with zero-mean of serially uncorrelated innovations.

[8] The variable GDPpc was from Maddison (2009) and is expressed with inflation adjustment in 1990 International Geary-Khamis dollars.

An important prior step when modeling VEC models is to determine the allocation of variables from the most endogenous moving to exogenous variables. As our dependent variable of interest is I_g, we allocate GDPpc in second place and $_{25}q_0$ as the more exogenous variable. Hence, the long-run we are interested in is:

$$\Delta \text{Ig}_t = \theta(Ig_{t-1} - \beta_1 GDPpc_{t-1} - \beta_2 25q0_{t-1} - \mu) \qquad (2)$$

Where θ is the error correction term or the speed of adjustment to the long-run equilibria which correct distortions from one period to the next. This coefficient must be between -1 and 0, so by simple algebra, the interpretation of the long-run coefficient should be interpreted with the opposite sign.

As Table 1 shows, the tests indicate that GDPpc and $_{25}q_0$ are I(1) as a constant. The variable I_g is more problematic, since the tests do not yield a common, stable result, even though it is true that some of them indicate that the series is stationary as a constant or constant and trend. A large number of the differences between the tests are probably due to the interpolation of the census data that we had to perform in order to carry out the study. For this reason, as well as because of the similarities between graphs I_g and $_{25}q_0$, we made I_g stationary at the first difference, always taking into account the constant or constant and trend when the test indicated that this was necessary. However, we must stress that we allowed ourselves to be guided by the ADF results. Where neither ADF nor PP rejected the null hypothesis, we transformed the variable into a stationary one, taking into account the KPSS test.

[Table 1 here]

Table 2 shows the lags indicated by the different tests that are generally used in the bibliography on time series. We used the AIC test to model the variables in the subsequent VEC model, mainly because SC and HQ often yield very small lags. We deviate from the parsimonious rule when selecting the optimal lag length because we consider that the theoretical relationship between the variables requires a greater lag interval. Nearly all classical representations of demographic transition depict a lagged decline of birth rates (Cleland, 2001: 60). Couples' reproductive decisions are conditioned by the mortality level that they experienced some years before in the places where they lived. In periods when mortality falls swiftly (as was the case during the demographic transition) couples cannot be certain whether the improved mortality rates will last or whether this is just a passing phenomenon. It is understandable that couples will adjust their fertility according to the mortality levels that they observed 8-10 years previously. Hence, the decision on increasing the family is not just based on short term changes over periods such as 3 to 5 years, as has been pointed out by SC and HQ.

[Table 2 here]

Once the cointegration relations had been analysed (Table 3) we proceeded to model the variables in the short term using the lags indicated, and introducing the equations of cointegration proposed by the Johansen test (1991 and 1995). Table 4 shows the results of the relations between the variables in the long term. The short-term results are not shown, because they were not significant and because the aim of this study was to test the convergence of variables in the long term.

[Table 3 here]

As the notes to Table 4 suggest, some countries were modeled taking into account structural changes, since these may at times affect the respective error correction term, resulting in positive values[9]. Once the structural changes are included in the form of exogenous binary variables, the error correction term returns to its usual range between -1 and 0, expressing the rate of correction of shocks from one period to another for each cointegration equation. We considered the ordering of the variables within the equation based on the expected contemporaneous and lagged impact of any shock in the variables. I_g can have a contemporaneous effect on GDPpc and $_{25}q_0$, but our working assumption is based on the idea that neither GDPpc nor $_{25}q_0$ has a contemporaneous effect on I_g. This ordering is also outlined in Nicolini (2007). In our case, our working assumption is that $_{25}q_0$ is, in comparative terms, more exogeneous than the GDPpc, since the sources of change of GDPpc are an uncountable, and $_{25}q_0$ merely comes from biological sources, alongside diseases and casualties from war. GDPpc will thus have the second position and $_{25}q_0$ will hold the third. Secondly, following this order, the cointegration rank was tested by means of the Johansen cointegration test, reported in Table 3. Where cointegration was found between two variables, the notation in Table 4 is as follows: 1 is for the first variable entering the cointegration, and the second variable entering the regressions is the one that is significant. When the three enter a single cointegration, I_g shows 1 as before, but now the two other variables are significant. Finally, when two cointegrations are found 1 points out which variable is entering the cointegration, while 0 points out which one is not entering, as explained below the table.

[Table 4 here]

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[9] We tested the residuals of the cointegrated regressions from Table 4 on autocorrelation and we display the results on Table A4 in the Appendix.

One aspect that is particularly noticeable is the high coefficient of determination (R^2). In the analysis of time series, this coefficient often lacks the information load that is found in the non-dynamic models, as it is influenced by the number of coefficients in the regression (number of lags for each variable) or by the time progression. In this case, the coefficient obtained was so high because of the high explanatory load of the lags in I_g included as independent regressors, which meant that the dependence between the value of I_g at t and t-j is very high.

Lastly, the dynamics of each country are captured by the different cointegration equations obtained. While for most countries, GDPpc and ${}_{25}q_0$ have a long-term relationship with I_g, in a few there is a long-term relationship between I_g and ${}_{25}q_0$, and a different one between GDPpc and ${}_{25}q_0$.

The results shown in Table 4 allow us to confirm that in the 15 countries analysed there was indeed a long-term causal relationship between the intensity of mortality and the trends in marital fertility. That is, an increase (or decrease) of ${}_{25}q_0$ in the long term means an increase (or decrease) of I_g (the variables move together and do not follow different paths)[10].

On the other hand, the results shown in Table 4 also point to the existence of other long-term relationships. In concrete, in England and Wales, Sweden, Italy and New Zealand, we may note a relationship between ${}_{25}q_0$ and GDPpc which differs from the relationship between ${}_{25}q_0$ and I_g. This indicates that the heterogenicity of the countries

[10] These results are obtained by multiplying the error correction term (significant and negative) with the coefficient of the variable ${}_{25}q_0$ (also significant and negative) from Table 4.

in question leads to different specific dynamics, without detriment to the expected relationship between $_{25}q_0$ and I_g[11].

5- Panel cointegration

As a complement to the statistical tests explained above, we also carried out a panel dynamics study of the same 15 countries shown in Table 4. To do this, we first obtained the cointegration equations by using tests such as those of Kao (1999) and Fisher (1932)[12].

Table 5 shows the results of the unit root tests including both the constant and the trend in an individualized way. The results point to an order of integration I(1) that is a constant.

[Table 5 here]

The results shown in Table 6 illustrate the cointegration relations in the panel and individually. In the case of panel cointegration, we find sufficient evidence to reject the null hypothesis that there is no cointegration, which means that we accept the alternative

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[11] The cases of England and Wales and Sweden should be stressed, where the error term in the second equation of cointegration is not within the expected range (-1 to 0). This issue could not be solved by including exogenous binary variables, and better specification of this model is certainly needed. Such a detailed study falls outside the scope of this article, although the problem of lack of specification could be solved – at least partly – by the panel study of countries explained later in this paper.

[12] For Fisher's tests we extracted 3 lags obtained from Table 2. We will thus focus on lags of 8, 9 and 10.

hypothesis of cointegration in the panel of countries. In the individual case, we find results which warrant special attention. To summarize the results that are stable across the different time lags, we need to mention that Sweden has no cointegration relationship; Spain, USA, Portugal and Germany have a cointegration relationship, while Denmark, England and Wales have two cointegrations. The other countries vary if we change the time lag. For this reason, we adopted the following analytical strategy: First, we computed a cointegration regression for the whole panel (15 units); second, we analysed only the case of countries with a cointegration equation (4 units); thirdly, we added those countries with 1 and 2 cointegrations (6 units) and finally, we added Sweden, which is the only country with no cointegration.

[Table 6 here]

Table 7 shows the results of the panel cointegration to explain the dependent variable I_g (marital fertility). One result shared by all the models calculated is that the relationship between I_g and ${}_{25}q_0$ is always significant at a level of 1% and has a positive impact, that is, an increase (or decrease) in mortality raises (or depresses) marital fertility in the long term, that is, these two variables do not go in different directions.

[Table 7 here]

On the other hand, it is evident that the long-term impact of GDPpc on I_g is negative and highly significant, but with some exceptions in the dynamic models (DOLS)[13]. This means that the increase in the GDPpc has a negative impact in the long

[13] This sporadic loss of significance can be explained by the fact that the model is calculated with a constant and a trend. In dynamic cases where only the constant is taken into account, GDPpc is highly significant and negative.

term on marital fertility. Although the relationship between the GDPpc and marital fertility does not fall within the scope of this article, we consider that it is interesting to draw attention to the causal relationship that emerged here. What this data is telling us is that, from the time of the earliest available information in the second half of the 19th century until the present day, the increase in GDPpc has been pushing marital fertility lower and lower. Historically, children were the safest investment that a couple could make to insure against future difficulties in life (illness, accidents, ageing). When parents' purchasing power increases, they become economically more independent from their children, finding alternatives to the traditional strategy of procreation as the only way of preparing for future adversities.

These results are important for two reasons: on the one hand, they support the trend found in the study for each country, overcoming possible omissions or lack of specification; and on the other hand, we obtain robust general causal results in the long term, controlling for different groups of countries (despite the discrepancies in the results of the cointegration tests, as can be seen from Table 6).

6- <u>Conclusions</u>

This article analyzes the long-term relationship between mortality and marital fertility, controlling for other potential determinants (GDPpc), in a panel of 15 countries from the early 19^{th} century onwards. Although the positive relationship between mortality and fertility was questioned by the results of research carried out under the auspices of the PEFP, when modern econometric techniques (panel cointegration) are applied they allow us more accurately to assess the changes in demographic phenomena over time. These methods were practically unknown at the time of the PEFP. Brown and Guinnane (2007) were right pointing out that when these statistical methods are used, the role of socioeconomic factors in the historical decline of fertility is restored.

The results of the present study using aggregated data on a national scale are fully in line with those of recent projects using micro data from family reconstructions (Van Bavel and Kok, 2010; Reher and Sanz-Gimeno, 2007; Reher and Sandström, 2015; Van Poppel et al., 2012; Reher et al., 2017), and they confirm one of the basic tenets of the classical theory of the demographic transition, which posits that the decline in mortality led to a decrease in fertility.

The results of our study justify the considerable efforts made to gather the information collected in order to obtain as detailed an overview as possible of the demographic transition in these countries. Although some researchers have advised against using aggregated data to analyze reproductive decision (which are individual in nature), the truth is that the results we obtained confirm, to a high degree of statistical significance, the traditional hypothesis concerning the theory of the demographic transition. Despite the doubts voiced by some researchers about the use of aggregated data for analyzing the demographic transition, our study shows that the use of macro data (even on a national level) can be extremely useful for developing our understanding of the historical decline in fertility, when the appropriate time analysis techniques are applied. One task for the future will be to test whether the application of the methodology used here to aggregated data from smaller areas (from provinces, for example) also confirms the relations we have detected in this study of the historical relationship between mortality and fertility.

In other studies similar to our own, mortality and fertility indicators have been used which we consider to be less than appropriate, either because they are affected by the changing population structure (CBR and CDR) or because they may be heavily influenced by the changes in marriage rates (as are all the indicators of total fertility). We made use of more refined indicators of mortality (${}_{25}q_0$) and marital fertility (I_g), and found that declining mortality leads to declining marital fertility. These results are the same, irrespective of whether the VEC, DOLS or FMOLS models are used. The conclusions of our research leave little room for doubt that both before and during the transitional period, mortality played a fundamental role in conditioning historical marital fertility levels[14]. With these new econometric techniques, we have confirmed the main paradigm of the classic demographic transition theory that was questioned by the PEFP.

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Table 1. P-values of unit root test

	I_g			$_{25}q_0$			GDPpc		
	ADF	PP	KPSS	ADF	PP	KPSS	ADF	PP	KPSS
Belgium	0,277	0,611	0,676 *** c	0,059	0,000	0,045 b	0,000	0,000	1,172 *** c
Denmark[d]	0,066	0,277	0,238 *** tc	0,001	0,000	0,236 *** tc	0,000	0,000	1,411 *** c
England and Wales	0,693	0,908	0,220 *** tc	0,000	0,000	0,063 b	0,000	0,000	1,309 *** c
Finland	0,034	0,371	0,148 ** tc	0,000	0,000	0,121 b	0,000	0,000	1,166 *** c
France[a]	0,004	0,098	0,109 b	0,000	0,000	0,040 b	0,000	0,000	0,027 b
Germany	0,504	0,472	0,218 *** tc	0,621	0,377	0,665 ** c	0,000	0,000	1,230 *** c
Italy	0,022	0,323	0,208 ** tc	0,000	0,000	0,035 b	0,000	0,000	1,105 *** c
Netherland	0,021	0,084	0,115 b	0,000	0,000	0,497 ** c	0,000	0,000	1,167 *** c
New Zeland	0,065	0,101	0,101 b	0,379	0,007	1,049 *** c	0,000	0,000	0,513 ** c
Norway	0,206	0,060	0,419 * c	0,027	0,000	0,124 * tc	0,000	0,000	1,371 *** c
Portugal	0,027	0,114	0,066 b	0,120	0,029	0,145 ** tc	0,000	0,000	1,230 *** c
Spain	0,044	0,125	0,420 * c	0,036	0,000	0,163 ** tc	0,000	0,000	1,097 *** c
Sweden	0,009	0,046	0,236 *** tc	0,000	0,000	0,099 b	0,000	0,000	1,350 *** c
Switzerland	0,126	0,163	0,700 ** c	0,042	0,000	0,135 * tc	0,000	0,000	0,888 *** c
USA	0,014	0,085	0,066 b	0,000	0,000	0,126 ** c	0,000	0,000	1,250 *** c

Just in this table, the asterisk means that we do not reject the null hypothesis of KPSS: Series is stationary.
Significance level: * 10%, ** 5%, *** 1%.
(a) time-frame 1875-2008, (b) not significant at 10% with or without trend, (t) trend included, (c) constant included, (d) time frame 1870-1970. ADF and PP were computed in first difference with constant as prior analysis in levels revealed unit root in the three series.
The parameters employed for the lag length of the unit root tests are as follows:

1) ADF- Automatic selection Schwarz information Criteria with a maximum of 30
2) PP- Spectral estimation method (Bartlett Kernel); Automatic selection by Newey-west bandwidth
3) KPSS- Spectral estimation method (Bartlett Kernel); Automatic selection by Newey-west bandwith

Table 2. Lag length criteria

	LR	FPE	AIC	SC	HQ	Interval
Belgium	8	8	8	3	3	1870-2008
Denmark	8	8	8	3	3	1875-2008
England and Wales	8	8	9	3	3	1853-2008
Finland	8	8	8	3	3	1882-2008
France	8	8	9	3	4	1875-2008
Germany	8	8	9	3	4	1868-2008
Italy	10	10	10	3	5	1870-2008
Netherlands	9	9	9	3	3	1861-2008
New Zealand	10	10	10	3	10	1870-2008
Norway	9	9	9	3	4	1820-2008
Portugal	8	9	9	3	3	1870-2008
Spain	8	8	8	3	8	1862-2008
Sweden	8	8	8	3	8	1820-2008
Switzerland	8	9	9	3	8	1870-2008
USA	10	10	10	3	3	1850-2008

Table 3. Cointegration test.

Finland (8 lags)				
Null	*Trace statistic*	*0.05 Critical value*	*Prob.*	
None	32.943	29.787	0.021	**
At most 1	8.134	15.494	0.451	
At most 2	0.494	3.841	0.481	

Denmark (8 lags)				
Null	*Trace statistic*	*0.05 Critical value*	*Prob.*	
None	35.088	29.787	0.011	**
At most 1	14.693	15.494	0.064	
At most 2	0.052	3.841	0.818	

England and Wales (9 lags and trend)				
Null	*Trace statistic*	*0.05 Critical value*	*Prob.*	
None	73.107	42.915	0.000	**
At most 1	36.891	25.782	0.001	**
At most 2	12.085	12.517	0.06	

Belgium (8 lags)				
Null	*Trace statistic*	*0.05 Critical value*	*Prob.*	
None	42.782	29.787	0.001	**
At most 1	16.314	15.494	0.037	**
At most 2	1.139	3.841	0.285	

France (9 lags)				
Null	*Trace statistic*	*0.05 Critical value*	*Prob.*	
None	47.625	29.787	0.000	**
At most 1	11.577	15.494	0.178	
At most 2	3.287	3.841	0.07	

Germany (9 lags and trend)				
Null	*Trace statistic*	*0.05 Critical value*	*Prob.*	
None	65.646	42.915	0.000	**
At most 1	28.418	25.782	0.023	**
At most 2	8.956	12.517	0.183	

Italy (10 lags)				
Null	*Trace statistic*	*0.05 Critical value*	*Prob.*	
None	36.794	29.787	0.006	**
At most 1	16.286	15.494	0.037	**
At most 2	3.28	3.841	0.070	

Netherland (9 lags)				
Null	*Trace statistic*	*0.05 Critical value*	*Prob.*	
None	34.340	29.787	0.014	**
At most 1	14.534	15.494	0.069	
At most 2	2.813	3.841	0.100	

Norway (9 lags)				
Null	*Trace statistic*	*0.05 Critical value*	*Prob.*	
None	31.575	29.787	0.030	**
At most 1	10.984	15.494	0.212	
At most 2	0.207	3.841	0.649	

Sweden (8 lags)				
Null	*Trace statistic*	*0.05 Critical value*	*Prob.*	
None	36.69	29.787	0.006	**
At most 1	17.183	15.494	0.027	**
At most 2	0.311	3.841	0.577	

Spain (8 lags)				
Null	*Trace statistic*	*0.05 Critical value*	*Prob.*	
None	45.189	29.787	0.000	**
At most 1	10.793	15.494	0.224	
At most 2	1.113	3.841	0.291	

Switzerland (9 lags)				
Null	*Trace statistic*	*0.05 Critical value*	*Prob.*	
None	46.773	29.787	0.000	**
At most 1	9.895	15.494	0.288	
At most 2	0.205	3.841	0.650	

New Zeland (10 lags)				
Null	*Trace statistic*	*0.05 Critical value*	*Prob.*	
None	36.574	29.787	0.007	**
At most 1	16.404	15.494	0.036	**
At most 2	3.841	3.841	0.298	

USA (10 lags)				
Null	*Trace statistic*	*0.05 Critical value*	*Prob.*	
None	40.784	29.787	0.001	**
At most 1	13.013	15.494	0.114	
At most 2	1.572	3.841	0.209	

Portugal (9 lags)				
Null	*Trace statistic*	*0.05 Critical value*	*Prob.*	
None	37.197	29.787	0.005	*
At most 1	10.952	15.494	0.2145	
At most 2	0.179	3.841	0.671	

Significance level: * 10%, ** 5%, *** 1%.
Reject null hypothesis at 5% level

Table 4. Cointegrated regressions

	ΔI_g	Δ GDPpc	$\Delta_{25}q_0$	C	Error Correction	Adjusted R^2	Obs.	Period
Belgium (8 lags)[1]	1	0	-1,99 ***	-0,04	-3,00E-03 ***	0,99	92	1870-2008
			0,350		*8,00E-04*			
	0	1	3745,3	-5434,3	-1,14E-09			
			2296,7		*1,20E-07*			
Denmark (8 lags)	1	-9,42E-06 **	-1064,0 ***	-0,20	-1,00E-03 **	0,99	180	1875-2008
		5,40E-06	*0,222*		*5,00E-04*			
England and Wales (9 lags and trend)	1	0	-4936,0 ***	1532,0	-7,00E-04 ***	0,99	146	1853-2008
			0,969		*3,00E-04*			
	0	1	-64785,4 ***	24321,1	1,80E-07 **			
			5963,7		*6,00E-08*			
Finland (8 lags)[2]	1	2,89E-06	-1096,0 ***	-0,28	-7,00E-03 ***	0,99	118	1882-2008
		2,50E-06	*0,278*		*2,00E-03*			
France (9 lags)[3]	1	9,29E-06	-1572,0 ***	-0,15	-5,00E-03 **	0,94	122	1875-2008
		5,90E-06	*0,337*		*2,00E-03*			
Germany (9 lags and trend)	1	0	-1487,0 ***	-0,14	-1,60E-02 ***	0,99	130	1868-2008
			0,094		*4,00E-03*			
	0	1	-63251,3 ***	2731,8	-2,94E-07 **			
			2924,57		*1,40E-07*			
Italy (10 lags)[4]	1	0	-1150,0 ***	-0,20	-3,00E-03 **	0,99	126	1870-2008
			0,152		*1,00E-03*			
	0	1	34784,5 ***	-13342,5	-4,98E-08 **			
			7411,3		*2,10E-08*			
Netherlands (9 lags)	1	-4,81E-07	-0,91 ***	-0,37	-3,00E-03 **	0,98	138	1861-2008
		6,10E-06	*0,133*		*1,00E-03*			
New Zealand (10 lags)	1	0	-10285,0 ***	0,26	-1,20E-02 ***	0,98	101	1870-2008
			2255,0		*3,00E-03*			
	0	1	469625,8 ***	-37685,9	-2,49E-07 ***			
			106257,0		*8,20E-08*			
Norway (9 lags)	1	0,001	-56165,0	1,00	-2,38E-05 *	0,98	179	1820-2008
		4,00E-04	*16672,0*		*1,40E-05*			
Portugal (9 lags)	1	1,73E-05 ***	-0,76 ***	-0,36	-9,00E-04 ***	0,99	98	1870-2008
		2,80E-06	*0,038*		*3,00E-03*			
Spain (8 lags)	1	3,25E-05 ***	-1010,0 ***	-0,40	-2,62E-04 ***	0,99	137	1862-2008
		4,30E-05	*0,081*		*9,90E-04*			
Sweden (11 lags)	1	0	-3333,0 ***	-0,10	-4,00E-03 ***	0,98	180	1820-2008
			0,440		*1,00E-03*			
	0	1	-60641,2 ***	3872,1	7,16E-08 ***			
			23545,60		*2,00E-08*			
Switzerland (9 lags)	1	1,19E-05	-2231,0 ***	0,02	-5,00E-04 *	0,99	123	1870-2008
		2,80E-05	*0,897*		*3,00E-04*			
USA (10 lags)	1	5,29E-06 ***	-1401,0 ***	-0,27	-4,00E-03 *	0,98	129	1850-2008
		1,33E-06	*0,080*		*2,00E-03*			

Significance level: * 10%, ** 5%, *** 1%
Standard error in italics.

Note: 1 in first column means that I_g is the dependent variable in the cointegration equation. 0 means that the variable does not get into the long-term equilibria.
[1] Including one dummy 1870-1930 = 1
[2] Including 3 dummies 1882-1912 = 1; 1913-1931 = 2; 1932-1962 = 3.
[3] Including 3 dummies, 1875-1912 = 1; 1913-1930 = 2 and 1931-1972 = 3
[4] Including one dummy, 1975-2008 = 1
Time-frames were chosen by estimating least squared breakpoints

Table 5. Panel unit root test (15 cross-sectional units)

		Level constant		Level, constat and trend	First difference and constant	
I_g	*Im, Pesarant and Shin Wstat*	0,797		0,985	0	***
	ADF-Fisher	0,787		0,721	0,002	***
	PP-Fisher	0,099		1	0,000	***
$_{25}q_0$	*Im, Pesarant and Shin Wstat*	0,178		1	0	***
	ADF-Fisher	0,063	*	1	0	***
	PP-Fisher	0,001	***	0,987	0	***
GDPpc	*Im, Pesarant and Shin Wstat*	1		1	0	***
	ADF-Fisher	1		1	0	***
	PP-Fisher	1		1	0	***

Table 6. Panel cointegration tests

	Residual variance	HAC Variance		t-statistic		Prob.	
Kao Residual cointegration Test[1]	3,00E-05	0,00018		-3,052		0,0011	
Fisher[2] (combined Johansen test)		Null: none		Null: at most 1 cointegration		Null: at most 2 cointegrations	
		<0,05	>0,05	<0,05	>0,05	<0,05	>0,05
	8 lags	Denmark England and Wales Finland France Germany Netherlands Norway Portugal Spain Switzerland USA	Italy Belgium New Zealand Sweden	Denmark England and Wales New Zealand Sweden Switzerland	Belgium Finland France Germany Italy Netherland Norway Portugal Spain USA		Belgium Denmark England and Wales Finland France Germany Italy Netherland New Zealand Norway Portugal Spain Sweden Switzerland USA
	9 lags	Belgium Denmark England and Wales Finland France Germany Italy New Zealand Portugal Spain USA	Netherland Norway Sweden Switzerland	Belgium Denmark England and Wales New Zealand Sweden Switzerland	Finland France Germany Italy Netherland Norway Portugal Spain USA	Italy	Belgium Denmark England and Wales Finland France Germany Netherland New Zealand Norway Portugal Spain Sweden Switzerland USA
	10 lags	Belgium Denmark England and Wales Germany Netherlands New Zealand Norway Portugal Spain Switzerland USA	Finland France Italy Sweden	Belgium Denmark England and Wales New Zealand Switzerland	Finland France Germany Italy Netherland Norway Portugal Spain Sweden USA		Belgium Denmark England and Wales Finland France Germany Italy Netherland New Zealand Norway Portugal Spain Sweden Switzerland USA

[1] Null: no cointegration. Automatic lag length criteria based on AIC with a maximum of 12

[2] Countries are mentioned in the null hypothesis column if it would be rejected in their case at a 5% level of significance

Table 7. Country panel cointegrating regressions (ΔI_g dependent variable)

	All countries				Countries with 1 cointegration equation			
	FMOLS[1]		DOLS[2]		FMOLS		DOLS	
	Constant	*Constant and trend*	*Constant*	*Constant and trend*	*Constant*	*Constant and trend*	*Constant*	*Constant and trend*
Δ GDPpc	-8,21E-06 ***	-3,74E-06 ***	-5,01E-06 ***	-6,92E-07	-7,49E-06 ***	-3,49E-06 *	-7,04E-06 ***	2,91E-07
	9,73E-07	*1,11E-06*	*6,97E-07*	*1,08E-06*	*1,23E-06*	*1,91E-06*	*1,28E-06*	*2,32E-06*
$\Delta\ _{25}q_0$	1,033 ***	0,0793 ***	1,145 ***	0,881 ***	0,09 ***	0,856 **	0,946 ***	0,637 ***
	0,043	*0,094*	*0,032*	*0,084*	*0,906*	*0,124*	*0,049*	*0,166*
Adjusted R^2	0,88	0,92	0,91	0,93	0,91	0,93	0,92	0,94
0bs.	2267 (unbalanced)	2267 (unbalanced)	2248 (unbalanced)	2246 (unbalanced)	550 (unbalanced)	550 (unbalanced)	546 (unbalanced)	545 (unbalanced)
Units.	15	15	15	15	4	4	4	4
Period	1856-2008	1856-2008	1856-2008	1856-2008	1871-2008	1871-2008	1871-2008	1871-2008

	Countries with 1 and 2 cointegration equations				Countries with 1, 2 and no cointegration equation			
	FMOLS		DOLS		FMOLS		DOLS	
	Constant	*Constant and trend*	*Constant*	*Constant and trend*	*Constant*	*Constant and trend*	*Constant*	*Constant and trend*
Δ GDPpc	-7,99E-06 ***	-5,62E-06 ***	-5,57E-06 ***	-1,21E-06	-8,38E-06 ***	-8,05E-06 ***	-5,55E-06 ***	-4,52E-06 **
	1,09E-06	*1,65E-06*	*1,05E-06*	*1,81E-06*	*1,28E-06*	*1,94E-06*	*1,00E-06*	*1,52E-06*
$\Delta\ _{25}q_0$	0,985 ***	0,971 ***	1,072 ***	0,973 ***	1,007 ***	1,229 ***	1,11 ***	1,3104 ***
	0,039	*0,123*	*0,044*	*0,138*	*0,047*	*0,15*	*0,04*	*0,119*
Adjusted R^2	0,90	0,92	0,92	0,94	0,9	0,92	0,92	0,94
0bs.	893 (unbalanced)	893 (unbalanced)	886 (unbalanced)	886 (unbalanced)	1081 (unbalanced)	1081 (unbalanced)	1074 (unbalanced)	1072 (unbalanced)
Units.	6	6	6	6	7	7	7	7
Period	1860-2008	1860-2008	1860-2008	1860-2008	1854-2008	1854-2008	1854-2008	1854-2008

Significance level: * 10%, ** 5%, *** 1%

Standard error in italics.

[1] Fully-Modified OLS. Lag specification based on AIC information to compute long-run covariance and allowing for heterogeneous first-stage long-run coefficients

[2] Dynamic OLS. Automatic AIC information to select number of lags and leads