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by Gustavo De Santis, Sven Drefahl,
and Daniele Vignoli
(sven.drefahl@sociology.su.se)

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A Period TFR with Covariates for Short-Panel Data

Gustavo De Santis
University of Florence, Dipartimento di Statistica, Informatica, Applicazioni (DiSIA)
Sven Drefahl
Stockholm University, Demography Unit, Department of Sociology
Daniele Vignoli
University of Florence, Dipartimento di Statistica, Informatica, Applicazioni (DiSIA)

Abstract: This paper extends a recently proposed approach aimed at reconciling the most widely used macro-level indicator of fertility, the Total Fertility Rate (TFR), with estimates that derive from applications of Event History Analysis (EHA) to micro-data. Using cross-sectional or, as in this case, short panel data, group-specific fertility estimates can be obtained that are consistent with the period TFR for the entire population. Short panels are now relatively frequent in socio-economic research, and extending their use to demographic analysis allows researchers to encompass exogenous variables that are only rarely available or very imperfectly measured in retrospective surveys, among which income or, more generally, individual-level economic data. An additional merit of the proposed approach is that is avoids a few of the selection problems that frequently emerge with EHA (e.g. when applications are specific by birth order, or by marital status). An application to Italian data reveals that the fertility of all the subgroups that can be formed is extremely low, and, therefore, that no structural modification, no matter how large, would suffice to bring fertility back to replacement level. Behavioural changes are required to that end.

1. Introduction and purpose

The period Total Fertility Rate (TFR), the most widely used summary measure of fertility at the aggregate level, suffers from a few limitations. Two of these, in particular, concern us here. The first is that the TFR does not take individual behaviour into account, and this (together with progress in terms of both data collection and analytical methods) is the main reason why, in the second half of the 20th century, the scientific study of population has progressively adopted a micro-level perspective (Courgeau and Lelièvre, 1997), shifting "from studies of structures to studies of processes" (Willekens, 1991, 1999). Secondly, the TFR controls for the age distribution of the population, but disregards other potentially relevant structural characteristics, such as parity, education, or place of residence.

Recently, however, a renewed interest in the link between macro- and micro-level research has emerged (Voss, 2007), and several scholars now emphasise the importance of keeping both dimensions into account, in order to better understand, for instance, contemporary fertility and family dynamics (Matysiak and Vignoli, 2010).

A recent paper by Hoem and Mureşan (2011a) bridges this gap explicitly, because it reconciles a macro outcome, the TFR, with covariates of fertility that act at the micro level, the effects of which are estimated with Event History Analysis (EHA), and are thus "net" of all the other explicitly considered covariates (see also Hoem and Mureşan, 2011b, or Hoem, Jalovaara and Mureşan, 2013). This paper pursues their line of reasoning and shows that their approach can also be applied to a new type of data, short panels, which are not forward-, and not backward-, looking, i.e. use panel follow-up and not retrospective questions. Short panels are becoming increasingly common in modern social sciences: examples are the ECHP (European Community Household Panel), the EU-SILC (European Survey on Income and Living Conditions) and all kinds of national Labour Force Surveys (with rotating panels). With short panels, individuals and households are observed for too short a lapse of time to follow their entire life course, and, indeed, these datasets are normally designed for the study not of fertility, but of economic behaviour, for instance, saving and labour force participation. Sufficiently detailed retrospective fertility questions are normally lacking in these surveys and in some cases there may even be no question at all on fertility, to the point that even the births that take place in the (short) period under consideration must be inferred indirectly from changes in the household roster[1]. These short panels permit analysts to calculate, among other things, period Total Fertility Rates (TFR), but this is seldom done because this measure is almost

[1] At round t+1 of the survey, a child aged 0 appears, who was not there at round t, and his/her mother can be identified only indirectly, by looking at the relationships within the household ("spouse of person of reference"; "child of person of reference"; etc.), which is essentially a modern variant of the own-children method of fertility estimation (Cho, Retherford and Choe, 1986)

always available from some other, more reliable source and because, until now it could not be related to individual characteristics and behaviour. With Hoem and Mureşan's (2011a) approach, however, one can easily estimate a summary fertility measure that is basically a period TFR with covariates. Among these covariates, some may not be available, or only very imperfectly measured, with retrospective questions: e.g. economic conditions (income, for instance), fertility intentions and desires (Régnier-Loilier and Vignoli, 2011; Testa, 2012), happiness and confidence in the future (Baranowska and Matysiak, 2011), or kin and environmental characteristics.

2. From EHA to TFR

Fertility micro-data are frequently analyzed with logistic regression or, as in this paper, EHA (e.g. Allison, 1984). A panel of subjects (normally women, sometimes couples) are observed over a long time span, with the purpose of estimating the likelihood of a birth in each subgroup (or sub-period), relative to a reference group/period. The covariates that are observed at the beginning of each period can be interpreted as determinants of higher or lower fertility with respect to a reference group. The interest is typically not in the absolute level of fertility, but in the relative distance between an arbitrarily-chosen reference group (e.g. married women, aged 25-29, with low education, and unemployed) and the others, differing by one characteristic at a time (the "cause" under scrutiny), with everything else equal.

The original methodology has evolved considerably in recent years, for instance with multi-process modelling (Matysiak, 2009), which tackles issues of endogeneity and selection into specific conditions (or careers), and fixed-effect models, which correct for selection on time-invariant (for instance, maternal) characteristics. Each of these approaches, however, tends to increase the complexity of the theoretical framework, and the link between the empirical results of these applications and the general fertility level of the population becomes less and less evident.

Hoem and Mureşan's (2011a) paper makes a step in the opposite direction and highlights the connections between EHA and TFR. In their application to the Romanian 2005 GGS (Gender and Generation Survey) sample, containing detailed retrospective questions, they estimate

1) $$\varphi_{xtgjk} = a_{xt}b_g e_j u_k$$

where "piecewise constant childbearing intensities" φ's depend on the basic time factor a_{xt} for age x and time t, which combines (multiplicatively) with a few covariates: birth parity b_g, education e_j, and rural/urban residence in childhood u_k.

The sum of these "age-specific intensities" (=monthly rates) gives a "Total Intensity Rate"

2) $$\mathrm{T}\vartheta\mathrm{R}_{rt} = \Sigma_{\mathrm{x}}\, a_{xt}$$

(both the label and the symbol are our own), for year *t* and for the reference category, which, in their case, is a woman who spent her youth in an urban environment, and has parity 0 and low education.

With a proper calibration of the parameters (i.e., scaling), the estimated $T\vartheta R_t$ may match exactly the official TFR_t in the reference year, and come very close to it in every other year. The effect of education, parity and residence in childhood emerge as inflators or deflators of the baseline $T\vartheta R_t$.

3. Short panel data

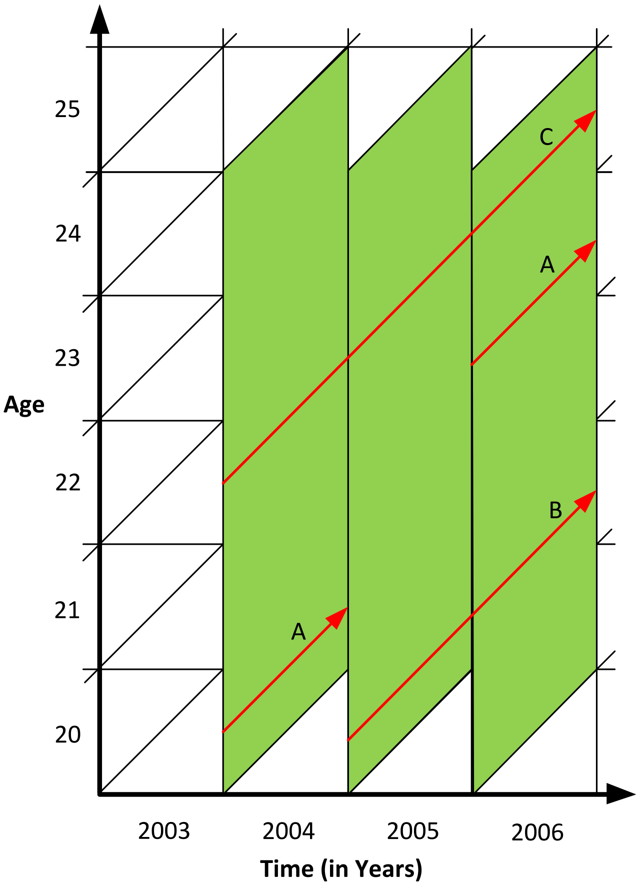
In this paper, Hoem and Mureşan's (2011a) ideas are applied to a dataset of a different kind: the four waves of the Italian section of the EU-SILC, 2004-2007. The EU-SILC survey is the statistical data reference source for comparative income statistics for the European Union and has been taken yearly in each member state since 2004: it collects detailed longitudinal information on the social and economic characteristics of individuals (aged 16 and over) and households. In our application, the analysis focuses on women who were first interviewed in 2004, 2005, or 2006, and re-interviewed at least once, twelve months later (in 2007 at the latest), and were thus observed for 1 to 3 consecutive years. Weights are provided by the Italian National Institute of Statistics to correct the biases that may derive from the complex sampling scheme and from non-response.

This type of data, with repeated observations during a limited time window, is becoming increasingly common in social sciences: examples are the ECHP (the predecessor of the EU-SILC), Labour Force surveys, and income surveys, like the Bank of Italy SHIW (Survey on Household Income and Wealth). These surveys are not designed for demographic research: their focus is, instead, on current socio-economic conditions (income, labour market participation, help given to and received from kin and friends, etc.), and on the subsequent (short term) changes. in these surveys retrospective questions are rare, if not totally absent, which is a drawback, of course, since demographic insight is scarce. Occasionally, as with the EU-SILC for instance, there are no direct questions on births - not even on current births, let alone birth histories: the birth of a child in the period under study must be inferred from changes in the household composition between two successive waves of the survey[2].

The use of this dataset introduces a few differences from Hoem and Mureşan's case. The first is that long - much less so, complete - life histories are not available here; merely short observations, lasting at most 3 years (women observed from 2004 to 2007, of type C in Figure 1), but in some cases 2 years (women of type B) or even only 1 year (type A).

[2] Which implies that infant mortality determines a small underestimation of fertility, because the children who are born and die very shortly after their birth go unnoticed in the survey. But infant mortality was very low in Italy in the period examined (2004-6), about 3.7 per thousand and it is surely not the main cause of worry about data quality.

Figure 1 - Lexis diagram for the selection of women in the dataset (Italian EU-SILC, 2004-7)



Note: Arrows represent women who are considered only if they have been interviewed at least twice, in any two consecutive years, between 2004 and 2007. Interviews were not actually conducted at the beginning of each year, but since, for the sake of simplicity, in this paper fertility is imputed to the year of the interview, it is convenient to *imagine* that women have been interview on January, 1st. All the characteristics of women, including age, are observed and recorded at the beginning of *each* year, but are updated at every new round of the panel.

Table 1 - Woman years, birth and fertility (Italy, 2004-2006)

Age	Women	Births	Fertility
16-19	1 472	4	2.6
20-24	2 123	34	16.3
25-29	2 224	127	57.1
30-34	2 669	206	77.3
35-39	3 026	124	40.9
40 and older	2 561	26	10.2
Total	**14 075**	**521**	**1 018.9**

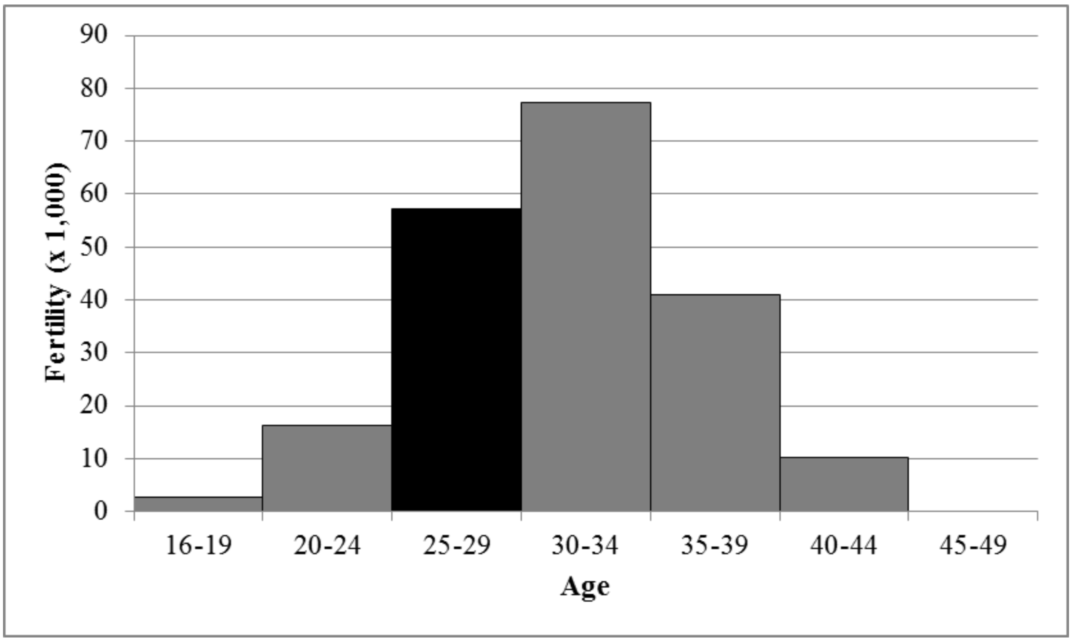
Note: Weighted data. Fertility rates are for 1,000 women.

Source: own elaboration on Italian EU-SILC data, 2004-2007.

The sample is made up of women who have been interviewed in any two consecutive years between 2004 and 2007: some of their characteristics (=covariates) are registered at the beginning of the 12-month period and, by looking at changes in the composition of the household, it is possible to ascertain whether they have had children, and how many, in the 12 months that separate two interviews. If a woman is interviewed three times, she remains under observation for two years, and she contributes twice to the data set (women of type B in Figure 1). If she is interviewed four times, she contributes three woman-years (women of type C in Figure 1). In all cases, her characteristics (e.g. age and employment status) are registered at the beginning of each (12-month) period of observation. In total, there are slightly more than 14 thousand women under observation in our 3-year window and little more than 520 births (Table 1).

This paper proposes a new type of period fertility analysis, trying to reconcile macro indicators (TFR) with micro-covariates, along the lines indicated by Hoem and Mureşan (2011a). In order to attenuate random fluctuations, it seems preferable to combine the data for the three years of observation. Figure 1 provides an example of how to proceed: for each 5-year age group of women (e.g. 20-24 years), starting in 2004, 2005 and 2006, the observation spans 12 months and generates fertility rates (births/woman years). These rates reflect the general shape of the Italian fertility curve reasonably well (Figure 2), but they are not perfect. The estimated TFR is merely 1.02, as compared to the official value of 1.33 for Italy in those years. The average age at childbirth, instead, is only slightly higher in our case than in the official data (31.6 years, as opposed to about 31). In part, this pattern may depend on the underrepresentation of foreigners (about 3% in the sample, about 4.5% among residents), because foreigners in Italy have more children than Italians do, and earlier. But this omission cannot explain the entire gap between the two sources, because the fertility of Italian residents in Italy is estimated to be close to 1.2 children per woman (Gesano, Ongaro and Rosina 2007), still considerably higher than the 1.02 of this sample. Another possible explanation is that households that had just had a child were more frequently unavailable for re-interview, or had moved somewhere else and could not be located, and were therefore (selectively) dropped from the panel. Note that the overall average unit non-response rate for the period 2004-2007 amounts to 18.6% (for details see European Commission 2013).

Figure 2 - Estimated age-specific fertility in Italy, 2004-7



Note: $f_{25\text{-}29}$ is shaded differently because it is the reference age structure in this paper (see Table 2).
Source: own elaboration on Italian EU-SILC data, 2004-2007.

4. Modelling period fertility with covariates

The approach proposed in this paper is a standard discrete-time EHA application based on fertility rates observed in a "typical" calendar year (average of three consecutive years, 2004 to 2006). Model results are presented in table 2. Model 1 is the simplest: age is the only covariate and the estimated RR's (relative risks) simply reflect the estimated fertility rates of Table 2 and Figure 2. In other words, model 1 (based on EHA) and traditional fertility analysis are virtually identical if EHA includes *all* the age classes and refers to the entire sample of women, without stratifying or selecting them in any way (apart from age).

Model 2 enriches the picture, by including two covariates: parity and education. What emerges is that women of parity 1 (i.e. with one child, of any age, at the moment of the interview) were twice as fertile in the subsequent 12 months as those of parity 0. Conversely, those who had already had 2 children were less fertile (27% less than nulliparous), and those who had already had 3 were the least likely to have another child. These results are not as surprising as they may appear at first sight, because marital status is not controlled for in this application: several childless women do not have a partner; whereas women with (at least) one child are in most cases married, or at least have a co-residing partner (not shown here). Of course, marital status (or living arrangement, or a combination of the two) could be considered among the covariates, but this would introduce other forms of distortions, especially reverse causation, because in Italy most women who want a child enter a stable relation first.

Education affects fertility and the sign of the relation has changed recently (Rosina and Testa, 2009; Régnier-Loilier and Vignoli, 2011). At present it is women with medium (+26%) or high education (+30%) who have more children, while women with low education have fewer - everything else equal. But, of course, education does not act alone. A simple cross sectional analysis does not allow observers to disentangle the complexity of the interactions here, but what can be done in order to get a first, descriptive indication, is to include more covariates: not only age, parity and education, as in Model 2, but also (equivalent) household income, employment (of the woman) and area of residence (Model 3).

Table 2 - EHA Regression models for fertility in Italy 2004-6

	Model 1			**Model 2**			**Model 3**		
	RR		**SE**	**RR**		**SE**	**RR**		**SE**
Age of Woman									
up to 19	0.05	***	0.02	0.06	***	0.03	0.07	***	0.04
20-24	0.28	***	0.07	0.3	***	0.07	0.3	***	0.08
25-29	1			1			1		
30-34	1.35	**	0.18	1.27	*	0.18	1.25		0.18
35-39	0.72	**	0.11	0.74	*	0.13	0.71	*	0.12
40 and older	0.18	***	0.05	0.19	***	0.05	0.19	***	0.05
Parity									
0				1			1		
1				2.02	***	0.28	2.05	***	0.28
2				0.73	*	0.13	0.76		0.14
3+				0.44	*	0.21	0.47		0.22
Education Woman									
Low				1			1		
Medium				1.26	*	0.16	1.21		0.16
High				1.3	*	0.21	1.23		0.2
Household Income Tercile									
Low							1		
Medium							0.97		0.15
High							1.3	*	0.19
Activity Status Woman									
Working							1		
Unemployed							0.88		0.12
Not active							0.81		0.16
Region									
North							1		
Center							1.15		0.15
South + Islands							0.84		0.13
Constant	0.06			0.04			0.04		

Notes: *p<=.1, **p<=.05, ***p<=.01. Models results include missing categories and are adjusted for intra-group correlations. Source: own elaboration on Italian EU-SILC data, 2004-2007.

As expected, in most cases the significance of the parameters gets lost, because the number of observations is limited and because of cross-correlation between the covariates: for instance, it is mostly in the centre-north of Italy that women are employed and household (equivalent) incomes are higher - in part because prices, too, are higher (about 20% higher: De Santis and Maltagliati, 2013).

But even if not significant, and even if they cannot be interpreted causally, the estimated signs of the regression parameters go in the expected direction (and separate analysis on each single variable, or sub-groups of variables -not shown here-, confirms that this is indeed how these covariates and fertility are associated). Women from high-income households have more children, but, once again, this depends in part on the "partner effect": women without a partner are typically poorer and have fewer children.

Employed women have more children than others: more refined analysis should take into account the type of occupation (e.g. permanent vs. temporary), the working schedule (full time vs. part time) and the working status of the partner (see, e.g. Vignoli, Drefahl and De Santis, 2012), but, once again, the issue of selection would then have to be considered explicitly.

Finally, women from the South have fewer children, even after controlling for all the other variables, which is indeed a remarkable change in comparison to a still recent past in Italy. The finding is not new, but what is new is the simplicity with which the present analysis brings it to the fore, net of other covariates.

The same results can also be presented as in Table 3, where percentage distributions and relative ratios are translated into (rough) estimates of fertility levels of each population subgroup. It may be worth reminding our readers that the estimated values refer to period TFR, and are therefore subject to the well-known possible biases of tempo variations. This is particularly evident in the case of parity 1, which also suffers from a selection bias, in that it refers almost exclusively to partnered women (and, probably, women who live in recently-formed couples). But these highly fertile women are a mere 18% of the total. In all the other cases, the distortion seems to be less strong.

Note that the information of the TFR columns in Table 3 is the same as that in the RR columns, but it is easier to read. For instance, it appears very clearly that even the most fertile subgroups (women of high educational level, or of high income, or employed, or living in the Centre of Italy) are far from replacement level, and that no structural change, no matter how large, would suffice to bring fertility back (or even simply close) to that level. For instance, if all the Italian women were highly educated, fertility would move from 1.33 to 1.44; if they were all employed, fertility would reach

1.46; if they were all rich[3], fertility could climb to 1.58. The RR columns, more than the TFR columns, suggest that a *combination* of favourable circumstances could work: i.e. if women were (or were to become) more educated *and* richer *and* employed, etc. This may be true, in part, but surely not by the amount that a simple multiplication of relative fertility levels would suggest. It would ignore interactions and would therefore lead to highly biased results.

Table 3 - Rough estimates of TFR by population subgroup (Italy, 2004-6)

	%	**RR**	**TFR**			**%**	**RR**	**TFR**
	Parity					*Household income*		
0	*55.2*	1	1.20		Low	*33.5*	1	1.22
1	*18.1*	2.05	2.46		Medium	*33.4*	0.97	1.19
2	*21.3*	0.76	0.91		High	*33.1*	1.30	1.58
3+	*5.3*	0.47	0.56					
						Main Activity		
	Education				Working	*48.7*	1	1.46
Low	*35.1*	1	1.17		Unemployed	*10.2*	0.88	1.28
Medium	*48.9*	1.21	1.41		Not Active	*38.8*	0.81	1.18
High	*13.4*	1.23	1.44		Missing	*2.3*		
Missing	*2.6*							
						Region		
					North	*42.0*	1	1.38
					Center	*18.1*	1.15	1.58
					South+Islands	*39.9*	0.84	1.16
All	*100*		**1.33**		All	*100*		**1.33**

Notes: Subgroup TFRs forced to average 1.33 (official national average), given RR (from table 2) and percentage distribution of women. Weighted data. Source: own elaboration on Italian EU-SILC data, 2004-2007.

Of course, interactions may be included in the analysis - as Hoem and Mureşan (2011a) did, for instance - and this is indispensable if one is specifically interested in the possible effect of the combined action of two or more covariates. But this finer analysis is possible only if the number of observations allows it, and in all cases it comes at the cost of confounding the message that this paper wants to convey: with some approximation, a cross-sectional TFR with covariates can be *easily* computed on modern datasets, and this approach proves particularly useful on short panels.

[3] *Strictu sensu*, this assumption makes no sense here because low, medium and high income are expressed in relative terms, in these tables. But the finding can perhaps be interpreted more loosely: “if they all felt rich”.

5. Concluding remarks

The approach proposed by Hoem and Mureşan (2011a) has several merits. The first and perhaps most important is that it is very simple, and it gives an order of magnitude of the fertility level of various population subgroups which, combined with their relative weight in the population, “explains” how the general TFR is composed. In so doing, it reconciles the modern, micro analysis of fertility (EHA) with the aggregate measures that non-demographers are still more familiar with, and that are still needed if one wants to keep the general trend and characteristics of the process in sight.

Secondly, and this is the focus of this paper, it may be applied not only to the databases that are typical for fertility analysis, with detailed retrospective questions, but also to socio-economic surveys with short panels. In both cases the approach yields descriptive statistics about fertility, basically period TFR with covariates: its results cannot be interpreted causally, but they provide the general framework within which more refined analyses can be tried and must be interpreted.

The present application to the Italian case shows that despite relatively large fertility differences between selected subgroups, no subgroup reaches (or even approaches) replacement fertility. This means that structural modifications in the composition of the population can, at best, raise the Total Fertility Rate only marginally, and are not enough to avoid future population aging and decline: (major) behavioural changes are required to that end.

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