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Spatio-temporal geostatistical modeling for French fertility predictions

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ABSTRACT

Fertility evolution in France shows a countertrend compared to the common pattern of fertility in Europe. Based on aggregate statistics, such as the Total Fertility Rate (TFR), the population of France, as compared to all the other European countries, has one of the highest levels of fertility. The TFR has increased in the last 15 years although the growth rate is decreasing. Indeed the TFR shows a tendency to stabilize at around 2.0, as confirmed, with small variability, for each region. The aim of the paper is to propose spatio-temporal geostatistical modeling for the French TFR. In particular, a stochastic method for spatio-temporal prediction is proposed. Although time series analysis has been widely used to describe the temporal evolution of various demographic variables, recently increasing attention has also been given to the study of the spatial distribution of these variables. Thus, in this paper, geostatistical spatio-temporal tools are appropriately used to study simultaneously both the spatial and the temporal behavior of the regional TFR in France for prediction purposes.

1. Introduction

In recent decades, one of the major European demographic issues is the decline in the fertility rate: in many of the EU member States, the TFR is below the replacement-threshold of 2.0–2.1

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live births per woman. In particular, in 2011, 14 of the European member States registered a TFR lower than 1.50 live births per woman. In spite of this general situation, the TFR in France has been characterized by a systematic growth over the last decade; specifically, the French TFR has been equal to or greater than 2.0 since 2006. Moreover, in 2011, several French regions (57% of all French regions, 48% of the regions belonging to mainland France) had TFRs equal to, at least, 2.0 (Eurostat, 2013a). It is worth noting that this behavior of the fertility rate in France has occurred during the current very difficult period of financial and economic crisis. Increasing unemployment levels, as well as employment uncertainty and, in general, economic difficulties for the family, have delayed first parenthood but have had a modest effect on fertility in France (Pailhé and Solaz, 2012). The relationships between fertility and the postponement of parenthood, decline in marriages, increased birth control and greater economic uncertainty are not characterized by the usual well-known and empirically demonstrated explanations. As often stated, French family policies, which promote both large families and participation of mothers in the work force, by supporting the combination of work and family (McDonald, 2013), play an important role in keeping the TFR up. For these reasons, the French TFRs and correlated variables have been the subject of recent scientific studies (Pailhé and Solaz, 2012; McDonald, 2013), whose aims were essentially related to the investigation of the possible relationships between socio-economic variables and different demographic scenarios.

The above-mentioned features of the fertility level in France suggest another relevant aspect to be considered, that is, the spatial and temporal perspectives of the TFR for prediction purposes. Indeed, the TFR data set for the 21 regions of mainland France, over the nineteen-year span from 1993 to 2011, is characterized not only by a systematic temporal behavior, but also by a well-structured spatial distribution. In the literature, different forms of spatial analysis, such as spatial econometrics, geographically weighted regression, multilevel modeling, and spatial pattern analysis, have been applied to geospatial demographic data (Entwisle, 2007; Liverman et al., 1998; Voss, 2007; Weeks, 2004; Castro, 2007). It is worth mentioning some relevant articles in the context of fertility analysis and modeling (Balabdaoui et al., 2001; Potter et al., 2010; Lesthaeghe and Neels, 2002), as well as some prominent papers which apply geostatistical techniques in the context of fertility analysis: Guilmoto and Rajan (2001) used kriging to interpolate a continuous surface (India) from a sample of observations (a fertility index estimated for district headquarters). In particular, spatial correlation is computed with Moran's coefficient, a spatial measure based on correlogram. In Bocquet-Appel et al. (2002) the all-India drift rate of fertility change, since 1961, was obtained from kriged maps (reconstituted surfaces) of a fertility index drawn from the data of the four decennial censuses conducted between 1961 and 1991, at the district level. In Bocquet-Appel and Jakobi (1998) fertility values have been estimated using the procedure of universal kriging. However, the geostatistical techniques applied in the above mentioned papers were only used in a spatial context. The novelty of this paper is to propose geostatistical methods in order to study, in a joint and unified way, spatio-temporal demographic phenomena, without keeping apart space and time. Although the spatio-temporal geostatistical approach has been successfully applied in several scientific fields, such as hydrology, geology, climatology, it can be considered innovative in Demography. The spatio-temporal behavior of several demographic variables, often described by using complex deterministic functions, can be suitable analyzed through the space–time random field theory.

The main advantages of geostatistical techniques in modeling the demographic variable of interest are related to the possibility of:

(a) analyzing both the spatial distribution and the temporal evolution of the data, through a spatio-temporal correlation measure (variogram);
(b) choosing an appropriate spatio-temporal model for the systematic component. Note that there are no restrictions in the methods or in the models to be used to define the deterministic and systematic component.

This paper provides an introduction to the spatio-temporal random field (*STRF*) theory and its useful application in demography in addressing research and policy questions. In particular, the fertility rate in France is analyzed and predicted by using spatio-temporal kriging. The empirical characteristics of the TFR evolution in space–time are presented and the flexibility of the generalized product–sum model is highlighted, together with its power to capture spatial and temporal correlations. Finally,