Spatial variability of total fertility rate and crude birth rate in a low-fertility country: Patterns and trends in regional and local scale heterogeneity across Italy, 2002–2018

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A B S T R A C T

Fertility is a key process shaping long-term population dynamics. Distinctive fertility trends have characterized demographic transitions, exhibiting sequential periods of spatial convergence and divergence. This descriptive study investigates the spatiotemporal evolution of Total Fertility Rate (TFR) and Crude Birth Rate (CBR) at different geographical scales in Italy between 2002 and 2018. Descriptive statistics of the TFR and CBR values across geographical scales were computed and the associated maps were prepared for the most detailed spatial levels available; specifically, down to the municipality level. Spatial analysis at the provincial and municipality level was based on both global and local Moran's indexes. Southern Italy, a mostly disadvantaged region, was characterized by relatively stable fertility patterns; fertility then decreased following an opposite trend with respect to economic conditions. The reverse relationship was observed in Northern Italy. As such, economic expansion and recession impacted fertility more intensively in Northern Italy.

Keywords: Total fertility rate (TFR), Crude birth rate (CBR), Spatial autocorrelation, Local and regional demography, Italy.

1. Introduction

Fertility is a key demographic process contributing to population trends (Balbo et al., 2013; Goldstein et al., 2009). In addition to its fluctuations over time, the spatial dimension of fertility can also highlight how births affect demographic dynamics in a given area (Billari, 2015). Despite diversified population patterns, comprehensive analyses of (the changing) spatial regimes of fertility at different spatial scales – including the local scale – are relatively scarce in Europe (Campisi et al., 2020; Cazzola et al., 2016; Franklin & Plane, 2004; Kertzer et al., 2009; Klüsener et al., 2013; Vitali & Billari, 2017). This paper aims to examine spatiotemporal trends of Total Fertility Rate (TFR) and Crude Birth Rate (CBR) at different geographical scales in Italy. The evolution of fertility and births in Italy has been characterized by regional differences, especially between Northern and Southern regions (Vitali & Billari, 2017) but there are new opportunities for more granular local analysis, specifically at municipality level, that are mostly absent from demographic studies. At the macro-level Italy had traditionally high and regionally differentiated fertility levels in the 1960s that declined to its lowest-low levels in the early 1990s, with a moderate recovery of fertility with increased regional spatial heterogeneity in the late 1990s (Micheli, 2000). The fertility and births levels between urban and rural areas in Italy were clearly distinguished, and this exacerbated the economic divide between Northern and Southern Italy (Arpino & Tavares,

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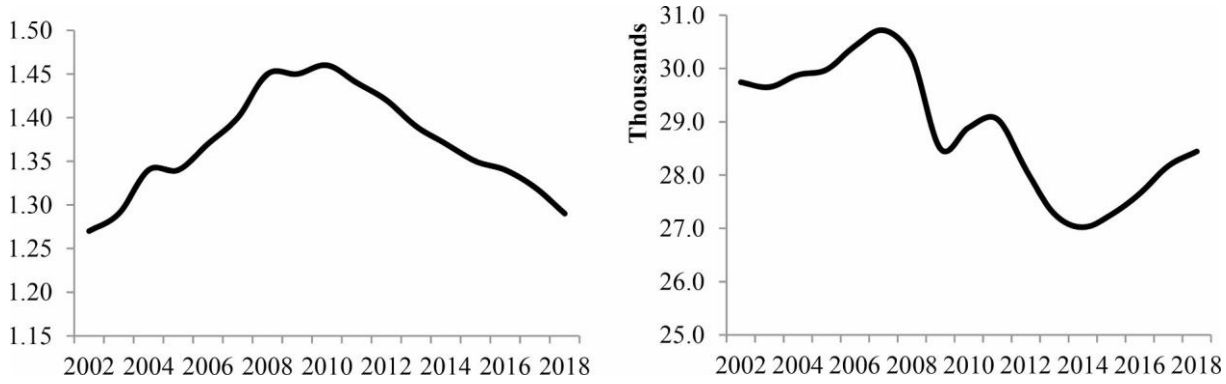

Fig. 1. Annual trends of Total Fertility Rate (TFR) (left panel) and per-capita Gross Domestic Product (GDP) (right panel) (*). 2002–2018, Italy. (*) World Bank, World Development Indicators, (http://data.worldbank.org/). Data are in constant local currency.

Table 1
TFR by administrative regions of Italy, 2002–2018 (bold indicate values at or above the national average).

Region	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Piedmont	1.20	1.22	1.27	1.28	1.33	1.37	1.42	1.43	1.44	1.45	1.43	1.41	1.40	1.36	1.35	1.34	1.28
Aosta Valley	1.24	**1.29**	1.33	**1.34**	**1.45**	**1.48**	**1.57**	**1.63**	**1.63**	**1.60**	**1.57**	**1.44**	**1.54**	**1.40**	**1.41**	**1.35**	**1.38**
Lombardy	1.25	1.27	**1.36**	**1.37**	**1.43**	**1.47**	**1.54**	**1.57**	**1.57**	**1.53**	**1.51**	**1.48**	**1.46**	**1.44**	**1.42**	**1.39**	**1.35**
Liguria	1.09	1.10	1.17	1.19	1.24	1.28	1.35	1.36	1.37	1.34	1.38	1.34	1.33	1.30	1.30	1.28	1.23
Trentino-A.A.	**1.45**	**1.46**	**1.55**	**1.55**	**1.55**	**1.57**	**1.62**	**1.59**	**1.65**	**1.62**	**1.63**	**1.62**	**1.64**	**1.63**	**1.64**	**1.62**	**1.59**
Veneto	1.24	1.26	**1.36**	**1.36**	**1.41**	**1.44**	**1.49**	**1.49**	**1.50**	**1.48**	**1.46**	**1.42**	**1.41**	**1.38**	**1.38**	**1.36**	**1.33**
Friuli-Venezia Giulia	1.12	1.16	1.21	1.24	1.29	1.34	1.36	1.38	1.40	1.38	1.39	1.37	**1.38**	1.32	1.33	1.31	1.28
Emilia-Romagna	1.24	1.24	1.33	**1.36**	**1.41**	**1.46**	**1.51**	**1.54**	**1.54**	**1.50**	**1.47**	**1.45**	**1.42**	**1.42**	**1.40**	**1.35**	**1.34**
Tuscany	1.18	1.16	1.28	1.28	1.31	1.36	1.42	1.39	1.42	1.40	1.39	1.35	1.35	1.30	1.30	1.28	1.25
Umbria	1.24	1.23	1.31	**1.34**	**1.37**	**1.40**	**1.45**	1.39	1.42	1.40	1.38	1.37	1.32	1.27	1.26	1.24	1.21
Marche	1.22	1.22	1.27	1.28	1.33	1.36	1.43	1.44	1.42	1.42	1.37	1.34	1.35	1.33	1.32	1.25	1.22
Latium	1.20	1.26	1.30	1.28	1.35	1.36	**1.48**	1.44	**1.46**	**1.48**	**1.46**	**1.42**	1.35	1.32	1.33	1.27	1.22
Abruzzo	1.14	1.19	1.21	1.23	1.23	1.28	1.33	1.31	1.37	1.35	1.34	1.30	1.29	1.28	1.28	1.24	1.19
Molise	1.15	1.16	1.14	1.15	1.14	1.18	1.19	1.14	1.24	1.19	1.18	1.17	1.16	1.17	1.15	1.19	1.09
Campania	**1.47**	**1.49**	**1.49**	**1.45**	**1.47**	**1.48**	**1.47**	**1.47**	1.45	1.43	1.39	1.35	1.32	1.34	**1.34**	**1.35**	**1.31**
Apulia	**1.30**	**1.30**	**1.34**	1.30	1.29	1.32	1.34	1.35	1.35	1.32	1.29	1.28	1.28	1.24	1.25	1.24	1.22
Basilicata	1.24	1.21	1.23	1.16	1.20	1.20	1.23	1.20	1.20	1.19	1.20	1.12	1.15	1.17	1.17	1.19	1.13
Calabria	1.23	1.27	1.27	1.26	1.30	1.30	1.30	1.32	1.32	1.30	1.29	1.28	1.27	1.29	1.28	1.28	1.26
Sicily	**1.40**	**1.43**	**1.44**	**1.43**	**1.43**	**1.42**	**1.45**	**1.45**	1.44	1.42	1.41	1.36	**1.38**	**1.35**	1.33	**1.35**	**1.34**
Sardinia	1.03	1.07	1.05	1.07	1.09	1.11	1.14	1.17	1.19	1.17	1.14	1.11	1.10	1.09	1.07	1.06	1.02
Italy	*1.27*	*1.29*	*1.34*	*1.34*	*1.37*	*1.40*	*1.45*	*1.45*	*1.46*	*1.44*	*1.42*	*1.39*	*1.37*	*1.35*	*1.34*	*1.32*	*1.29*

2013; Billari & Kohler, 2004; Zambon, Rontos, Reynaud, & Salvati, 2020).

1.1. Factors associated with the declining evolution of fertility and births in Italy

Several factors are associated with the declining evolution of fertility and births in Italy and with the differences existing in fertility and births trends between the Italian regions. A segmented and flexible labor market, difficulties in work-family reconciliation, and scarce childcare services constitute social and economic factors connected with the characteristics of the fertility evolution in Italy. The economic determinants and the relation between fertility and economic contexts was often the core of the studies about fertility and reproductive behaviors (Goldstein et al., 2013). In particular, the relationship between fertility and economic growth is the subject of a broad debate that originates from Malthus' original work and continues to the present day (Ashraf et al., 2013). The relevance of the relationship between fertility and economic conditions is arguably even greater when referring to sub-national contexts (Fox et al., 2019) and can highlight the importance of the geographical dimension in understanding population dynamics (Bocquier & Br´ee, 2018; Champion & Hugo, 2004). In this regard, the study of fertility and births assumes a particular relevance especially in relation to the local scale (Mucciardi & Bertuccelli, 2013). Italy is in fact composed of a multiplicity of municipalities that are very heterogeneous among themselves in terms of geographical and socio-economic characteristics and population dynamics (Reynaud et al., 2020). Ageing and consequent depopulation, poor accessibility, and the progressive social and economic marginalization of these territories are important issues closely linked to the dynamics of fertility and births (Reynaud & Miccoli, 2018). It is no coincidence that Italy has recently

adopted a national plan for the protection of these territories promoting actions to boost their demographic and economic growth.

1.2. The importance of the geographical levels in analyzing fertility patterns and trends

What happens at local (or the municipal) level is not independent from what happens at higher geographical levels such as provinces or administrative regions. That is, although it is important to examine the variability fertility rates while acknowledging the complex interplay of micro- and macro-factors of change (Rosti & Chelli, 2009; Gavalas et al., 2014; Zambon et al., 2019).

The attention to geographical levels is coupled with an analysis across a paradigmatic period in recent Italian history, 2002–2018, which incorporates pre-and post-economic crisis years (Salvati, 2016).

Table 2

CBR by administrative regions of Italy, 2002–2018 (bold indicate values at or above the national average).

Region	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Piedmont	8.5	8.6	8.8	8.7	8.8	9.0	9.1	9.0	8.8	8.7	8.5	8.1	7.8	7.5	7.2	7.0	6.7
Aosta Valley	9.2	**9.5**	9.6	9.4	**10.1**	**9.9**	**10.3**	**10.3**	**9.9**	**9.6**	**9.3**	8.3	**8.7**	7.7	7.6	7.2	7.2
Lombardy	**9.6**	**9.6**	**10.1**	**9.9**	**10.2**	**10.2**	**10.4**	**10.3**	**10.2**	**9.7**	**9.4**	**8.9**	**8.6**	**8.4**	**8.1**	**7.9**	**7.5**
Liguria	7.3	7.4	7.6	7.6	7.7	7.7	7.9	7.8	7.6	7.3	7.4	7.0	6.8	6.4	6.3	6.1	5.8
Trentino-A.A.	**10.9**	**10.9**	**11.3**	**11.0**	**10.8**	**10.8**	**10.8**	**10.4**	**10.6**	**10.3**	**10.2**	**9.9**	**9.8**	**9.6**	**9.5**	**9.2**	**9.0**
Veneto	**9.6**	**9.6**	**10.1**	**9.9**	**10.0**	**10.0**	**10.1**	**9.9**	**9.7**	**9.4**	**9.1**	**8.6**	8.2	7.9	7.7	7.5	7.2
Friuli-Venezia Giulia	8.1	8.3	8.4	8.4	8.6	8.7	8.6	8.6	8.5	8.2	8.1	7.7	7.5	7.0	7.0	6.7	6.4
Emilia-Romagna	8.9	8.9	9.3	9.4	**9.5**	**9.7**	**9.9**	**9.8**	**9.7**	**9.3**	**9.0**	**8.6**	8.2	**8.0**	7.8	7.4	**7.3**
Tuscany	8.4	8.2	8.9	8.8	8.8	9.0	9.3	8.9	8.9	8.6	8.5	7.9	7.8	7.3	7.2	7.0	**8.4**
Umbria	8.6	8.5	9.0	9.1	9.2	9.3	9.5	9.0	9.0	8.8	8.6	8.3	7.8	7.3	7.1	6.9	6.6
Marche	8.6	8.7	8.9	8.9	9.1	9.2	9.5	9.4	9.1	9.	8.6	8.2	8.	7.7	7.5	7.0	6.7
Latium	**9.5**	**9.8**	**10.0**	**9.7**	1.1	**9.9**	**10.6**	**10.1**	**9.9**	**9.9**	**9.6**	**9.1**	**8.6**	**8.2**	**8.1**	**7.6**	7.2
Abruzzo	8.4	8.6	8.7	8.7	8.6	8.8	9.0	8.7	9.0	8.7	8.5	8.2	7.9	7.7	7.6	7.2	6.8
Molise	8.1	8.2	8.0	7.9	7.7	7.9	7.9	7.5	8.0	7.6	7.4	7.2	7.0	7.0	6.7	6.9	6.2
Campania	**11.4**	**11.4**	**11.4**	**10.9**	**10.9**	**10.8**	**10.6**	**10.4**	**10.1**	**9.8**	**9.5**	**9.1**	**8.7**	**8.7**	**8.6**	**8.6**	**8.3**
Apulia	**10.0**	**9.9**	**10.1**	**9.6**	9.4	**9.5**	9.5	9.4	9.2	8.9	8.6	8.3	8.1	7.7	7.6	7.4	7.2
Basilicata	9.2	8.9	8.9	8.3	8.4	8.3	8.4	8.1	7.9	7.7	7.8	7.1	7.1	7.2	7.0	7.0	6.6
Calabria	9.2	9.4	9.4	9.2	9.3	9.2	9.1	9.2	9.1	8.8	8.7	8.5	**8.3**	**8.3**	**8.1**	**8.0**	**7.8**
Sicily	**10.3**	**10.5**	**10.4**	**10.2**	**10.1**	**9.9**	**10.0**	**9.9**	**9.6**	**9.4**	**9.3**	**8.8**	**8.8**	**8.5**	**8.2**	**8.2**	**8.1**
Sardinia	8.1	8.3	8.0	8.1	8.1	8.2	8.2	8.2	8.2	7.9	7.6	7.2	6.9	6.7	6.4	6.1	5.7
Italy	*9.4*	*9.4*	*9.7*	*9.5*	*9.5*	*9.5*	*9.6*	*9.5*	*9.3*	*9.1*	*9.0*	*8.5*	*8.3*	*8.0*	*7.8*	*7.6*	*7.3*

Some studies showed that the 2008 economic crisis exacerbated particular factors connected with fertility contributing to shape the trends and patterns in fertility and births evolution observed after 2008 (Goldstein et al., 2016; Lanzieri, 2013; Salvati et al., 2016). This study is based on the hypothesis that macro-scale fertility patterns in more recent years have taken on a more heterogeneous pattern reflective of increasingly fragmented and mixed micro-scale demographic behaviors. **2. Data and methods**

We start with a description of aggregate fertility trends in Italy focusing on the last 50–60 years as context to the more recent changes. This is followed by the introduction of our data and measures. Specifically, we use two measures of fertility (Total Fertility Rate and Crude Birth Rate) and accompanying sub-national data at the province and municipal levels that enable a more rigorous description and analysis of local patterns and trends over time (2002–2018). With data across scales we can use maps to zoom in and out describing national, regional, and local spatial patterns. We also leverage exploratory spatial data analysis methods to examine the spatial dependency in the fertility measures, again using annual data to compare results across time. We discuss our findings in the context of broad economic change, pre- and post- recession, and close with a more specific discussion about future directions for spatially informed research in very-low fertility contexts.

2.1. Study area

We start by presenting national data on fertility trends in Italy over the past 50–60 years. Italy was considered as an ideal case study due to particularly complex fertility dynamics after World War II, with a shift from high fertility in the 1960s to low fertility in the 1990s, which was then followed by a moderate and temporary recovery in the 2000s (Goldstein et al., 2009; Sobotka, 2004; Vitali & Billari, 2017). Italy reached the lowest-low fertility level in 1995 and then experienced fertility increases through to 2010. Since 2010 Italian fertility levels have decreased. Crude Births Rate (i.e., the number of live births in a year divided by the midyear population multiplied by 1000) dropped below the value of 10 per thousand by the end of the 1980s and by 2018 had declined further to 7 per thousand. In total, between 2008 and 2018 births experienced a decline of approximately 24 percent. The decline of the births in the last few decades is associated with both the continuing drop in the propensity to have children and by structural factors connected to the fertility decline of previous years. Indeed, the number of Italian women of reproductive age today is related to the fertility declines since the late 20th Century.

Woman who postponed fertility has likely contributed significantly to the fertility recovery in the 2000s (Billari et al., 2006), and so too did international immigration (Arpino & Tavares, 2013; Billari & Kohler, 2004; Kertzer et al., 2009). Over the last two decades, the resident population in Italy shifted from a 20-year period of modest increase to a new stage of demographic growth driven by intense net immigration (Gesano & Strozza, 2011). Foreigners residing in Italy increased from about 1.3 million in 2001 to over 4 million by 2011 (Strozza et al., 2016). At the last available data (January 2019), it is estimated that there are more than 5 million foreigners resident in the country. [3] The presence of the foreign-born in Italy is itself characterized by high levels of spatial heterogeneity with the metropolitan and urban areas – especially located in the North and Centre of the country – benefiting more than other areas from immigration (Strozza et al., 2016). Italy is an interesting case study as it is also a country with demographic dynamics representative of Southern Europe. The macroeconomic dimension likely plays a prominent role in contributing to fertility dynamics and trends. In the study years (2002–2018),

[3] Data are disseminated by the Italian National Institute of Statistics (Istat). Census data are available at http://dati.istat.it/, demographic data based on municipality registers are available at http://demo.istat.it/.

TFR and GDP per-capita trends reveal sequential waves of expansion and contraction (Fig. 1). In particular, the TFR increased from 1.27 in 2002 to 1.46 by 2010 and then fell back again to 1.29 by 2018. Per-capita GDP shows even more variability during the observed years: there is a first period (2002–2007) in which per-capita GDP grew from 29,741 to 30,717 Euros, then, a second period (2008–2014) of decline to a per-capita GDP in 2014 of 27, 021 Euros. Finally, in the last period (2015–2018) there was a sign of recovery, with per-capita GPD rising to 28,442 Euros by 2018.

It seems clearly reasonable to argue that the TFR trajectory in Italy was not independent from the dynamics of the macroeconomic context hit by a major economic and social crisis. This is even more relevant for an Italian economy still characterized by a deep regional divides between the North and Central regions, that are more economically diversified and with comparative high presence of immigrants, and Southern/Island regions, a less dynamic area with a comparatively low presence of immigrants (Benassi & Naccarato, 2018).

2.2. Data and indicators

This study examines the use of two measures—Total Fertility Rate (TFR) and Crude Birth Rate (CBR)—computed at different spatial scales. The TFR is a measure of the number of children a woman would have if, during her reproductive life, she was subject to the specific fertility rates of the year of observation. Therefore, the TFR indicates the average number of children per woman. The TFR was calculated at two spatial scales: administrative region (n =20) and provinces (n =110). The CBR is the number of live births in a year divided by the midyear population (multiplied by 1000). The CBR was calculated for three spatial scales: administrative region (n = 20), provinces (n = 110), and municipalities (n = 8102, 8094 and 7960 respectively in 2002, 2010 and 2018). By definition, the CBR is "crude" because it ignores who is at risk of having births and the age structure of the population. Nevertheless, the CBR was computed to help inform our understanding of local level (municipal) fertility as the TFR is not available at this finer level. Both TFR and CBR were computed focusing on a relatively short time interval (2002–2018) but covering both pre- and post-economic crisis years. Data were derived from the Italian National Institute of Statistics (ISTAT); all the relevant data are disseminated through their website (http://dati.istat.it/; http://demo.istat.it/).

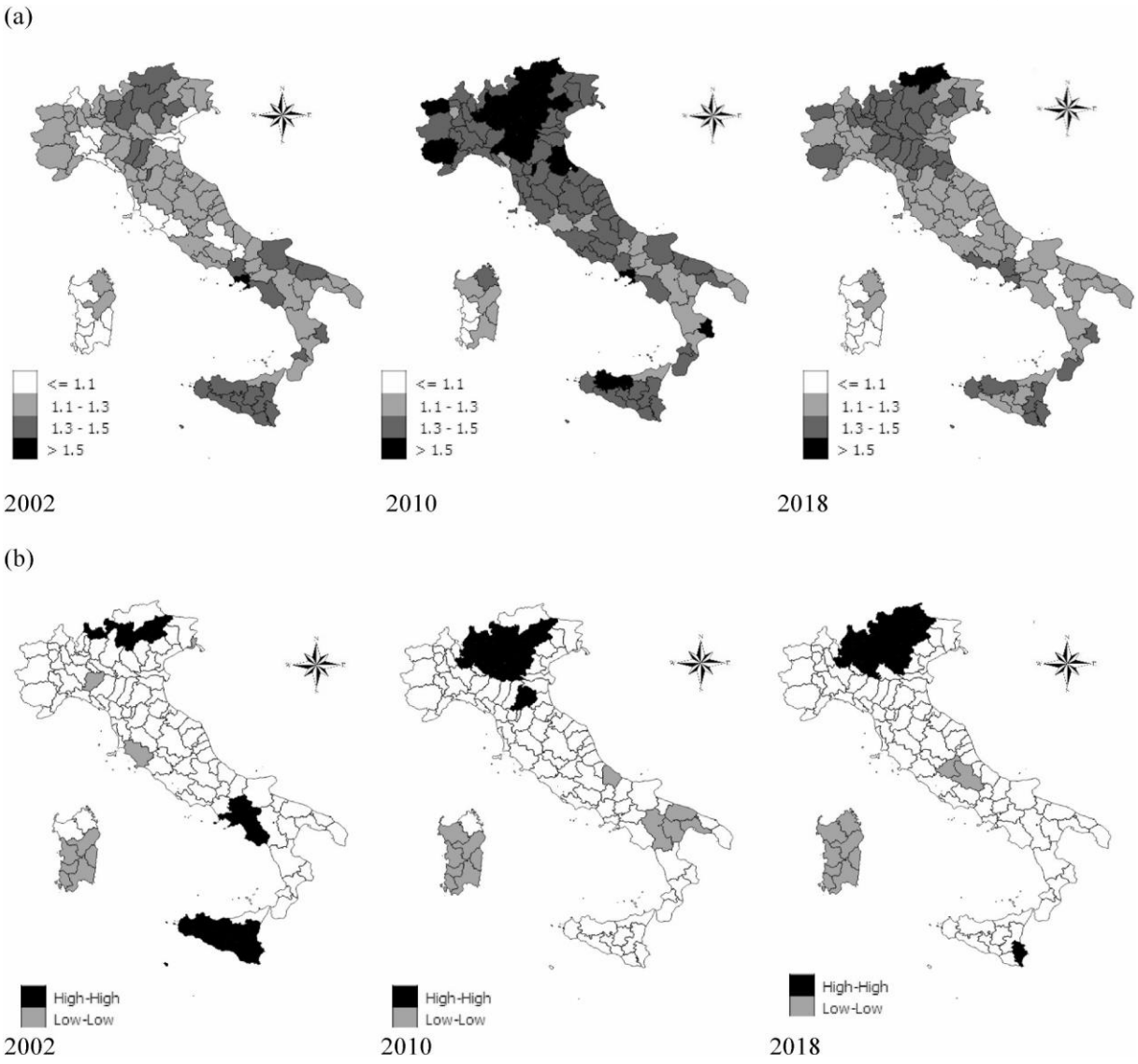

Fig. 2. TFR and Local Moran's index in TFR in Italy by province, selected years; (a) Spatial distribution of TFR among provinces; (b) Local Moran's index of spatial autocorrelation in TFR by province (significant spatial units in high-high and low-low spatial regimes were illustrated).

2.3. Statistical analysis

Descriptive statistics of the TFR values across spatial scales were computed for each year between 2002 and 2018 and the associated maps were prepared for the most detailed spatial levels (i.e., provinces and municipalities). An exploratory spatial analysis of TFR separately for each year between 2002 and 2018 was based on global and local Moran's indexes of spatial autocorrelation. The same approach was applied to CBR at municipal scale, and for the purposes of this study focusing on three years (i.e., 2002, 2010 and 2018). These three separate years correspond to the beginning and the end of the time period of focal interest, supplemented with the year with the highest fertility peak of the time series (i.e., 2010).

The global Moran's indexes were calculated separately using distance-based spatial weights matrices with multiple bandwidths (including 100, 150, 200 km). Distances among spatial locations was calculated using a Euclidean metric. The results are presented based on the z-score, which embodies a standardized value from Moran's I index, and the related significance value (*p*-level) under the hypothesis of a non-autocorrelated spatial structure of each fertility measures. A positive (and significant) Moran's I index indicates spatial dependence; conversely, a negative (and significant) Moran's I index indicates spatial dispersion. Maps of the local Moran's indexes of spatial autocorrelation are used to identify any significant local clusters of TFR and CBR that can be characterized as either homogenous spatial regimes (a combination of high-high or low-low attribute values among neighboring areas as defined by the spatial weights matrices[4]) or spatial outliers (derived from high-low or low-high patterns) (Anselin, 1995). We map the high-high and low-low clusters.

3. Results

Table 1 illustrates TFR trends at the regional level in Italy between 2002 and 2018. In the aggregate, fertility rates increased between 2002 and 2010 (from 1.27 to 1.46) and decreased at a similar pace in the following years, reverting back to a level similar to that observed in 2002 (i.e. 1.29 by 2018). As shown in

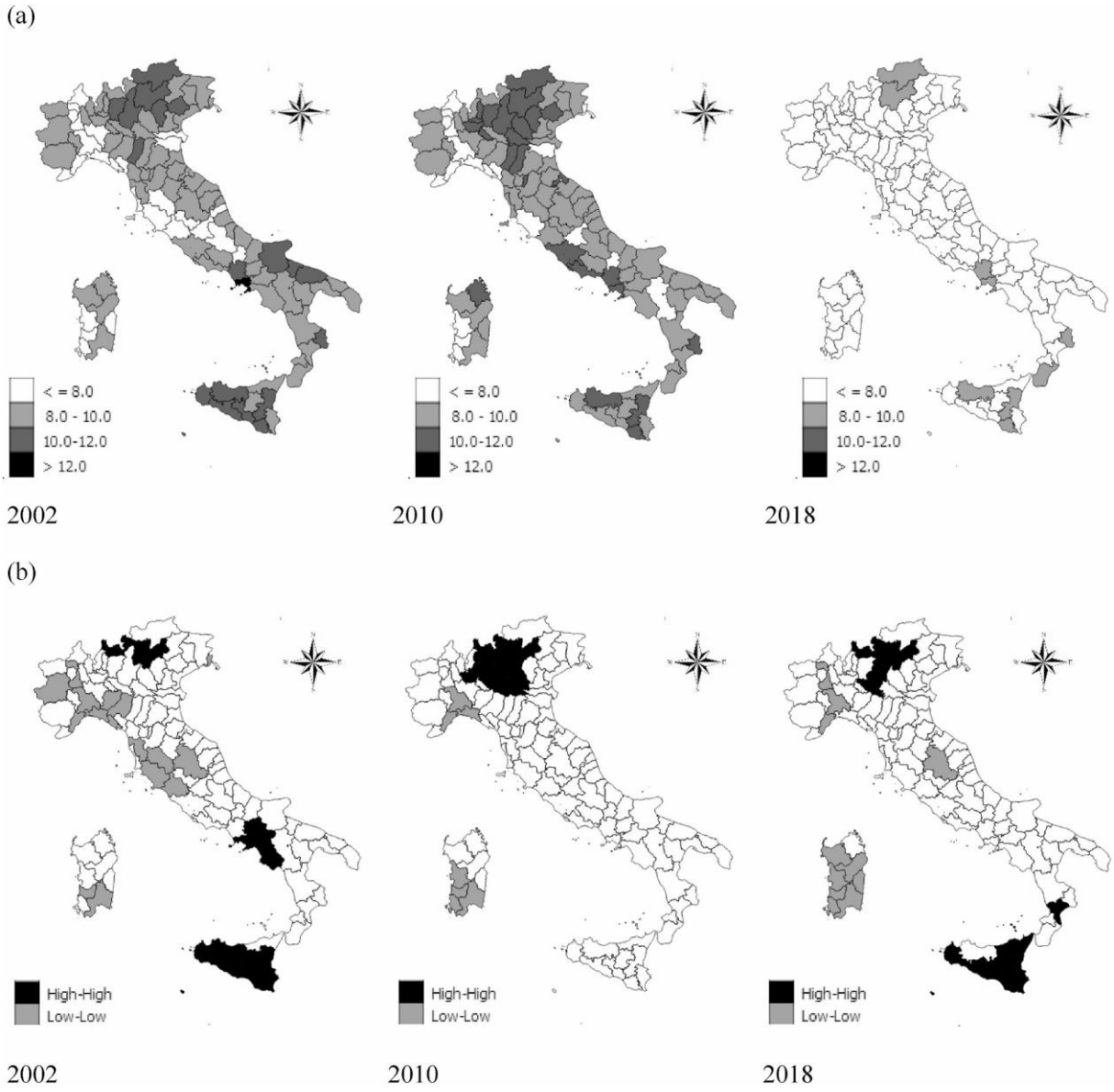

Fig. 3. CBR and Local Moran's index in CBR in Italy by province, selected years; (a) Spatial distribution of CBR among provinces; (b) Local Moran's index of spatial autocorrelation in CBR by province (significant spatial units in high-high and low-low spatial regimes were illustrated).

[4] It should be noted that for computing the local version of Moran's Index (Figs. 2b, 3b, 4b and 5b) we used a 'queen' contiguity spatial matrix of 1st order.

Table 1 eight administrative regions are consistently below the national average; and one consistently above (i.e., Trentino-Alto Adige). The regional trends of CBR in Italy in the same period (Table 2) show some similarities and differences. The CBR for Italy as a whole grew from 9.4 in 2002 to 9.6 in 2008. In the later years (2008–2018) CBR declined to 7.3 by 2018. Like for TFR, regional heterogeneity clearly affects the distribution of CBR. Nine administrative regions are consistently below the national average (one more compared to TFR) and four above (i.e., Lombardy, Trentino Alto Adige, Campania, and Sicily). At this level there is a certain amount of stability over time vis-a-vis at administrative and the national average: ` Piedmont is the obvious exception; Veneto, Latium and Apulia have been above but now are consistently below; Friuli Venezia Giulia mostly

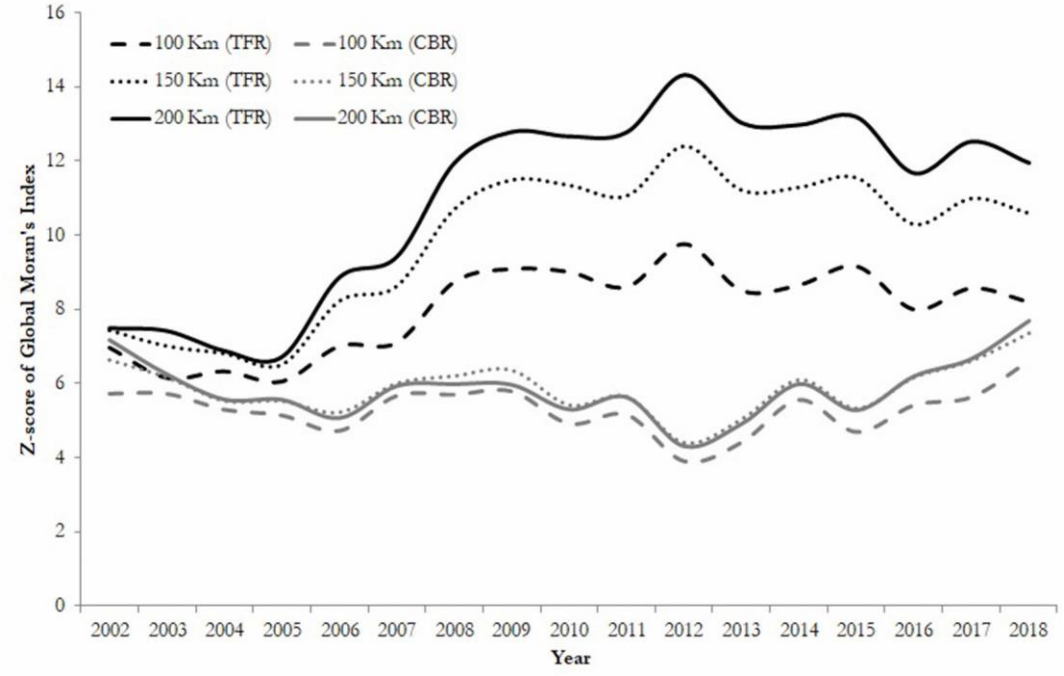

Fig. 4. Global Moran's index of spatial autocorrelation of TFR and CBR among Italian provinces, 2002–2018 by bandwidth (km) and year.

below though the gap has closed over time, and now hovers close to but below the national average.

The spatial distribution of TFR and of CBR were illustrated for three emblematic years (2002, 2010 and 2018) at the level of Italian provinces (Fig. 2a). With regard to TFR, in 2002, a marked spatial dichotomy was observed, distinguishing specific Northern provinces (e.g. those in Trentino region) and Southern ones (almost all of Sicily's provinces). In 2010, higher (and more scattered) rates of fertility were observed, mitigating the North-South divide. In many Northern provinces TFR's higher than 1.5 was observed. By 2018, spatial heterogeneity in the TFR was the dominant pattern: all Sardinia provinces had a low TFR over time (<1.3) and only few provinces in Southern Italy (Palermo, Catania, Crotone, and Naples) recorded relatively high fertility.[5] With regard to CBR (Fig. 3a), in 2002, the highest values are recorded by provinces located in both the North and the South. In the South, the province of Naples records the highest value followed by some provinces in Apulia region, the province of Caserta (in Campania region), and some provinces of Sicily. Higher comparative values in the North are recorded by the two provinces that form Trentino Alto Adige and also some provinces of Lombardy and Emilia Romagna. This pattern remains quite stable in 2010 but then, by 2018, we observe significant change. With maps using a constant legend to ease interpretation we see that by 2018 the CBRs are now found in the lowest data class (≤8.0) for almost all Italian provinces; the exceptions include a handful of provinces located in North Eastern and Southern Italy.

Local Moran's index of spatial autocorrelation was carried out for TFR and for CBR at the provincial scale. Fig. 1b illustrates the spatial distribution of the index for three significant years (i.e., 2002, 2010 and 2018). Significant spatial units in high-high and low-low spatial regimes were identified. The spatial patterns are similar to those noted above, with significant high-high index clusters almost continually observed in Northern Italy, predominantly in the Trentino-Alto Adige region and in some provinces of the Lombardy region. Specifically, in 2002, most of the Trentino-Alto Adige and Sicilian provinces, together with some provinces (e.g. Naples), stand out with higher TFR, resulting in hot spots. By 2010, following the economic crisis, the highest values of fertility expanded in many Northern provinces, close to the Trentino-Alto Adige region. By 2018, the situation seems to be a mix of the earlier years (2002 and 2010) but with clear high-high clusters in the North East and low-low in Sardinia. The situation related to CBR (Fig. 3b) is quite similar to the TFR, indicating similar spatial patterns and structures of dependency for these two measures.

We can look at data on these patterns in more detail. Fig. 4 reported the global Moran's index of spatial autocorrelation of TFR and CBR among Italian provinces, from 2002 to 2018 according to different bandwidths (km). From Tables 1 and 2 we know that the maximum fertility rate was reached in 2010 and the maximum of CBR in 2004 (similar to 2008). For the year 2010, the z-score for the global Moran's I of TFR is 9.01 at 100 km, increasing up to 12.67 at 200 km. For the year 2004, the z-score for the global Moran's I of CBR is 5.28 at 100 km increasing up to 5.58 at 200 km. These high values all indicate a strong spatial autocorrelation and the importance of spatial dependence on TFR and CBR.

The CBR values do not change with the spatial weights but the values for TFR increase as the bandwidth of the spatial weights increases. Notably, the CBR also is fairly stable over time. TFR increases of all spatial weights through 2007–2008 and then is relatively stable (in the aggregate).

Given the amount of data at municipal scale the analysis presented here focused on the years: 2002, 2010, and 2018. Fig. 5a illustrates that the CBR

[5] Descriptive statistics of the spatial distribution of TFR for all the Italian provinces were calculated during the same temporal period (2002–2018). These are available on request.

takes on a distinct spatial distribution over time. In 2002, a strong spatial heterogeneity emerges in Italy, making it difficult to identify extensive homogeneous regions. Indeed, in only a few contexts does there appear to be regional consistency (i.e., Trentino-Alto Adige and southern Sicily). New, and more spatially homogenous, clusters emerged in 2010 in Northern Italy and in several coastal areas (e.g., the provinces of Bari, Naples, Rimini and Rome, as well as the east coast of Sardinia). By 2018, the spatial distribution at the municipal level returns to a more fragmented patterning, with the exception of an enduring cluster in the Trentino-Alto Adige region.

4. Discussion

Demographic analysis has focused on population dynamics across time and space, attributing an increasing importance to long-range assessment of transformations in population structures (Lesthaeghe & Neels, 2002; Salvati & Carlucci, 2017; Vitali & Billari, 2017). Macro-scale investigation of fertility patterns and trends plays a crucial role in the literature (Billari, 2015; Campisi et al., 2020). At the same time, social modernization implying changes in lifestyles has determined a latent shift in traditional models of fertility

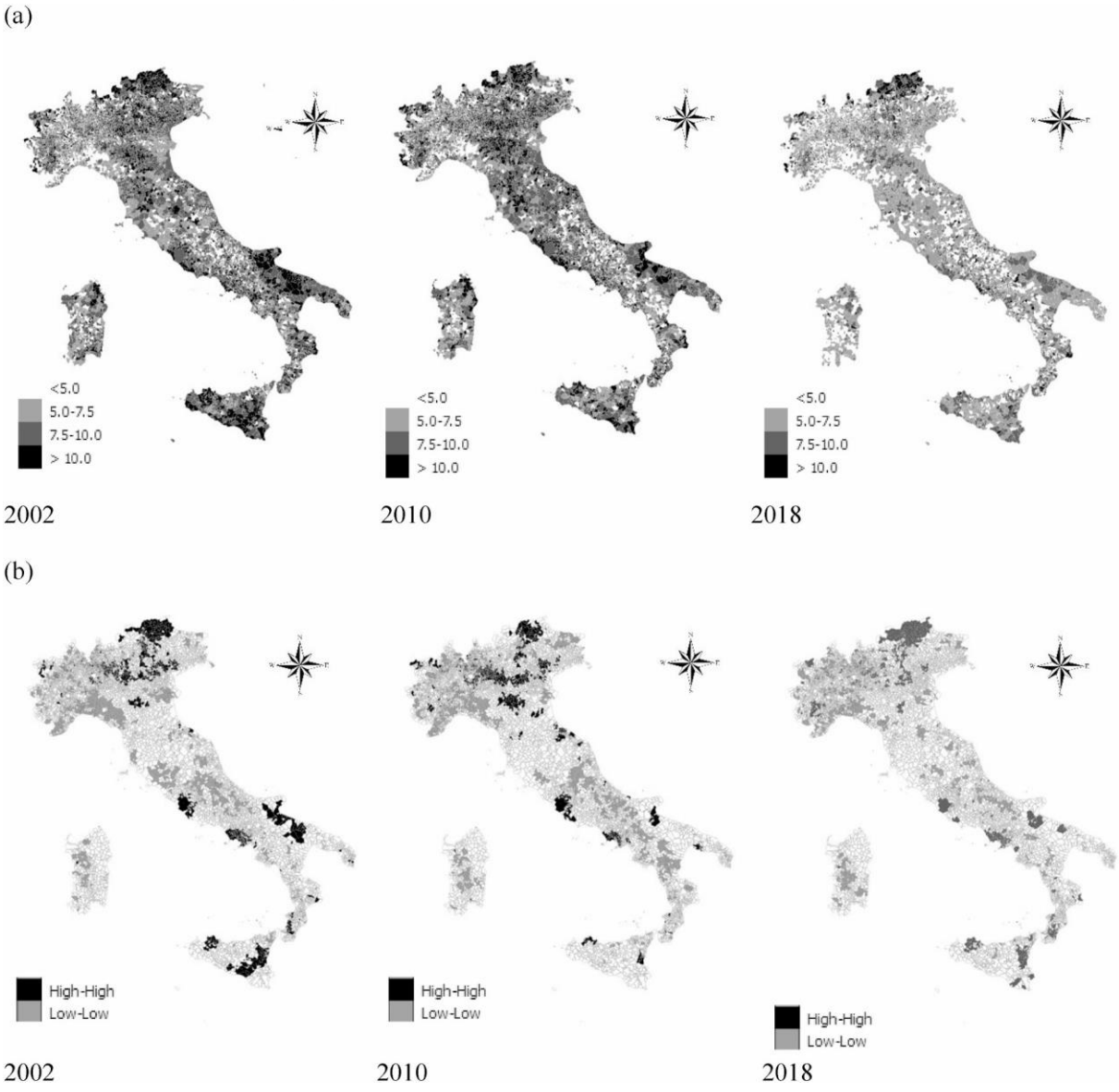

Fig. 5. CBR and Local Moran's index in Italy by municipality, selected years; (a) Spatial distribution of CBR among municipalities; (b) Local Moran's index of spatial autocorrelation in the CBR by municipality (significant spatial units in high-high and low-low spatial regimes were illustrated).

To better investigate spatial distribution, local Moran's index of spatial autocorrelation was calculated accruing to the values of CBR by municipality in Italy. Fig. 5b confirms the trends identified in Fig. 5a but specifically identifies the local clusters or types of local spatial regimes and their spatially patterning over time. We can observe an expansion of high values in the north and later a contraction around the core Northern areas. In Sicily and parts of Southern Italy, a more spatially homogenous pattern emerges in 2010 before the re-emergence of several high-high spatial clusters by 2018.

decisions, and more recent interpretative models investigating changes in propensity to marriage and childbearing reflects an increasing spatial heterogeneity resulting from increasingly mixed, fragmented, and less predictable individual choices, likely less and less connected with the traditional local context (Fent et al., 2013).

The descriptive results from this study suggest that fertility trends are in some way associated with economic downturns (Comolli, 2017; Kotzamanis et al., 2017; Salvati & Carlucci, 2017). The local and regional spatial analysis of fertility focusing on economic expansion (2002–2009) and recession (2010–2018) suggested a different sensitivity to economic downturns. Considering the results of the spatial structure, based on Moran's indexes of spatial

autocorrelation, we observed the spatial convergence with regions (spatial regimes) of fertility during the 2000s, coinciding with economic expansion. Fertility rates in Northern and Central regions increased more rapidly than in Southern Italy. With the economic crisis starting in approximately 2007 (Comolli, 2017; Fahlen´ & Olah, 2018´ ; Fiori et al., 2018), Northern and Central regions experienced a more rapid decline in fertility compared with Southern Italy (Goldstein et al., 2009; Vitali & Billari, 2017).

Spatially-varying response of fertility rate to economic expansions and recessions may highlight a differential elasticity of local contexts to economic factors, implying a several interrelated adjustment processes. Economic downturns appear to have had a more evident impact on spatial structures of fertility at the local scale. That is, the economic crisis was associated with progressively loss of traditional demographic structures that were once identified between urban and rural areas and between Northern and Southern regions of Italy.

Spatial dynamics of TFR in Italy are comparable to other Mediterranean countries, namely Greece and Spain (Arpino & Tavares, 2013; Kotzamanis et al., 2017), and even other European countries (e.g., in recent years, trends in Italian fertility resemble those recorded in Germany: (Billari & Kohler, 2004). Based on this premise, future studies that can explore spatiotemporal changes in fertility are essential to examine the increasingly multifaceted role of local contexts responding (faster or slower) to exogenous shocks and internal transformations of regions and districts. Studies which consider the variation of fertility and births at local levels, including comparisons across geographic levels, can provide a broader framework for understanding the nuanced temporal changes in fertility processes. Furthermore, such research can motivate the design and the implementation of scale specific policies aimed to counteract the negative demographic consequences, of fertility and birth decline.

Author statement

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