The diffusion of late fertility across European regions (2006–2018)

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Abstract

Late fertility has emerged as a landmark trend across high-income countries in recent decades. Previous research has largely attributed geographic disparities in the prevalence of this phenomenon to differences in socioeconomic contextual factors. Our study adds a new dimension to the understanding of late fertility development over time: the role of diffusion processes. We employ a comprehensive panel of 193 regions spanning 18 European countries to study the substantial increase in the contribution of late fertility rates to total fertility, rising from 16.6% in 2006 to 22.8% in 2018. We exploit regional variation in this increase to assess whether late fertility in a region is influenced by nearby regions' behaviour in preceding periods. To test this, we utilize a dynamic spatial Durbin model that captures both temporal and spatial interdependencies. Accounting for various factors known to affect late fertility rates, such as the tertiarization of education or changes in the opportunity structures within the economy, we find a significant link between geographic proximity and the rise of late fertility across European regions. This emphasizes the profound interconnectedness of contemporary societies. Thus, beyond socioeconomic transformations, our research provides empirical evidence for contagion process contributing to the spread of late births across the continent – which is likely to be relevant in shaping future fertility trends.

Keywords Late motherhood, fertility timing, postponement, recuperation, dynamic panel analysis, spatial dependence

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1. INTRODUCTION

In recent decades, there has been a marked increase in late fertility across high-income countries. While it used to be common for women to have children in their twenties, since the 1980s they have often waited until their early 30s to start a family. Consequently, it has also become increasingly prevalent for them to have a first or second child at age 35 and later (Beaujouan 2020a; Billari et al. 2007; Prioux 2005).

Despite late motherhood being a prevalent trend across all European societies, significant geographic variation exists. Studies have documented differences *between* (Beaujouan 2020a; Prioux 2005) and *within* countries (Campisi et al. 2022; Riederer and Beaujouan 2024; Šprocha and Fitalová 2022). These differences have largely been attributed to contextual factors which largely dominate individual and biological constraints (Beaujouan and Toulemon 2021:13). Within countries, economic related factors have proven relevant in explaining geographical differences, as they shape individuals' life goals and the opportunity costs associated with childbearing at later ages (Riederer and Beaujouan 2024).

While differences in late fertility across regions are acknowledged, the geographic mechanisms shaping them have yet to be fully understood. As late fertility rates began to increase in some areas earlier than in others (Beaujouan 2020a; Šprocha and Fitalová 2022), it is likely that their spread did not occurred randomly in space *and* time. Thus, beyond the stark influence of contextual factors, trends may follow a specific geographic pattern from their origin to other areas. Such diffusion processes can be shaped by the transmission of new ideas and information through social influence and learning (Bongaarts and Watkins 1996; Montgomery and Casterline 1996; Rogers 1983). It has already been evidenced for various behavioral changes, including historical fertility transitions (Brée and Doignon 2022; Costa, Bocquier, and Eggerickx 2021; Goldstein and Klüsener 2014), contemporary low fertility rates (Vitali and Billari 2017; Wu et al. 2022), and cohabitation behavior (Vitali, Aassve, and Lappegård 2015), showing how new behaviors spread geographically among adjacent areas. However, to date, whether this has applied to late fertility trends over time has been overlooked.

Understanding the geographic mechanism is crucial because a continued and intensified spread in late fertility could have significant socioeconomic and health implications. As more women have children later in life, they are likely to encounter issues such as increased health risks during pregnancy and delivery, coupled with a narrow reproductive window (Sauer 2015; Schmidt et al. 2012). To contextualize, a woman's likelihood of conceiving within a year drops from 75% at age 30 to 66% at 35 and 44% at 40 (Leridon 2004). If diffusion processes are found to be relevant, it is important to recognize that they play a role in amplifying increased rates, shaping future trends, and understanding that geographic differences may not solely be artifacts of evolving contexts.

Our study aims to bridge this gap by offering an unprecedented examination of the geographic mechanism driving the recent rise of late fertility across European regions, by accounting for heterogeneity in late fertility patterns across both time and space. We hypothesize that a contagion effect, i.e., that operates through geographic proximity, is a key driver in shaping the spread of late childbearing behaviors. Our analysis utilizes a balanced panel encompassing 193 regions across 18 European countries from 2006 to 2018. To test our hypothesis, we employ a dynamic spatial panel model and assess the influence of the contribution of late fertility rates to total levels in nearby areas in the previous time period $(t-1)$ on explaining the variation in late fertility in the current period (t). We control for relevant contextual factors known to impact late fertility rates (Riederer and Beaujouan 2024) to isolate the diffusion effect from changes in the socioeconomic environment (e.g. the spread of tertiarization of education). Hereby, our study also demonstrates the effectiveness of dynamic spatial panel modelling in elucidating the spread of demographic phenomena. This not only adds depth to our understanding of late fertility but also adds to the growing body of research that emphasizes spatial dependence.

2. BACKGROUND

The geography of late fertility

The upward trend of late fertility (above age 35) has been widespread across European countries in recent decades. While births at advanced ages are not a new demographic observation in themselves, the novelty of this trend lies in the emergence of delayed fertility behavior. Late births were already common in the early 1950s, but mainly at higher parities. Today's trend, however, revolves around postponing the birth of the first or second child (Beaujouan and Sobotka 2019). This shift coincides with a reduction in family size and the number of children people wish for, which averages two across the European continent (Sobotka and Beaujouan 2014). Although late fertility is universally observable, the onset and pace of this new behavior vary significantly across space (Beaujouan 2020a). This trend started in most Nordic and Western European countries in the early 1970s, and occurred later in Southern, and Central and Eastern Europe (CEE). Despite a later start of childbearing postponement, the pace of this increase was higher in Southern European countries, as they rapidly moved to the forefront and have exhibited the highest share in late fertility rates since the mid-2010s (Beaujouan 2020). Conversely, despite rising trends in births at advanced ages, most CEE countries still exhibit relatively low levels of late fertility.

Beyond cross-country differences, one may wonder whether these country-specificities persist within national territories. However, so far, subnational disparities in late fertility have received limited attention. Existing studies have limited scope, either covering a few countries over time (Campisi et al. 2022; Šprocha and Fitalová 2022) or a large number of contexts but at a single point in time (Riederer and Beaujouan 2024). These investigations consistently indicate higher late fertility rates in urban regions, possibly accompanied by a sharper rise compared to rural areas, as observed in Slovakia (Šprocha and Fitalová 2022). This is in line with a study of changes in the mean age at childbirth in a large set of European regions over time (Buelens 2021), yet providing only descriptive evidence of fertility postponement in general and not directly indicative of fertility trends in older ages.

Factors explaining geographical differences in late fertility

Geographical differences in late fertility across countries can largely be attributed to contextual factors (Beaujouan and Toulemon 2021:13). Within countries, economic-related factors have emerged as significant determinants of urban-rural differences in late fertility rates (Riederer and Beaujouan 2024; Šprocha and Fitalová 2022). In this vein, research underlines the central role of education, alongside the opportunity structures within the economy and the labor market.

Education, particularly the shift towards tertiary education, emerges as a key factor. Studies conducted at the subnational level consistently demonstrate a strong positive association between high educational attainment levels and late childbearing, contributing to the explanation of the rural-urban disparity (Campisi et al. 2022; Riederer and Beaujouan 2024; Šprocha and Fitalová 2022). This association is reinforced by the concentration of tertiary-educated individuals in urban areas compared to rural areas (Eurostat 2023; Riederer and Buber-Ennser 2019). The mechanism of how longer duration of education is associated with postponing childbirth is extensively elucidated at the micro level (Mills et al. 2011; Neels et al. 2017; Vasireddy et al. 2023): as more women pursue tertiary degrees, the completion of education occurs at later ages, and key demographic events such as starting a job, forming unions, and planning for a family also tend to be delayed.

The urban environment not only facilitates education but also provides economic opportunities. Across European regions, it has been shown that the more competitive regions tend to be, as measured by their ability to offer an attractive environment for firms and residents to live and work, the higher their GDP and the greater achievements[1] by women (Dijkstra et al. 2023:23). This association may be mirrored in late fertility rates. Research indicates that regions characterized by thriving economies and significant high-technology sectors also tend to exhibit higher rates of late fertility (Riederer and Beaujouan 2024). Similarly, Slovakian findings demonstrate that late fertility correlates with increasing wages and employment rates in the tertiary sector (Šprocha and Fitalová 2022). A corresponding socioeconomic profile of late mothers can be illustrated at the micro-level: they not only tend to possess higher education levels, but also tend to occupy middle or higher-level occupations, and possess greater socioeconomic resources (Toulemon 2005). One explanation for their late births lies in the conflict between motherhood and (a potential delay in starting) work, as individuals often prioritize career advancement to mitigate the wage penalty associated with early parenthood (Mills et al. 2011). Herein, the urban context may facilitate the achievement of financial stability and the likelihood of women catching up with delayed family plans, as it allows individuals to experience faster wage growth (Glaeser and Maré 2001).

Favorable economic conditions not only contribute to increased late childbearing behavior but also adverse ones. Young adults are particularly vulnerable to adverse conditions as they face higher risks of job loss during economic downturns and are often engaged in temporary or informal employment, leading them to postpone their plans for childbearing until later in life (Alderotti et al. 2021; Matysiak, Sobotka, and Vignoli 2021; Neels, Marynissen, and Wood 2024). At the subnational level, it has been shown that periods of economic downturn during the Great Recession were associated with fertility declines among young adults, especially in regions with deteriorating labor markets (Matysiak et al. 2021). Thus, adverse economic conditions not only impede achieving financial independence but also can influence reproductive decisions. Indeed, the income channel has become increasingly crucial for women as a prerequisite for parenthood across high-income countries over the past few decades (van Wijk and Billari 2024). Consequently, it may not be surprising that countries heavily affected by economic crises and grappling with a significant proportion of young adults detached from education and the labor market, such as Southern Europe, also exhibit high rates of late fertility (Beaujouan 2020a; Skirbekk 2022:200).

Prevailing values and norms can further contribute to geographic variations in late fertility. For instance, late parenthood is less prevalent in societies where having a child relatively early may be valued. This is suggested by Billari et al. (2011), who found a negative association between social age deadlines for childbearing and the rates of births of women of older ages. Similarly, perceptions of such social age limits for reproduction have increased between 2006–07 and 2018–19, along with (although not

[1] Achievement is quantified by a composite metric, the Female Achievement index, which shows the level of womens' achievement within a NUTS2 region relative to the region with the highest achievements. The index encompasses 33 indicators along seven domains: "Work & Money", "Knowledge", "Time", "Power", "Health", "Safety, Security & Trust" and "Quality of Life".

proportionally) upward trends in late births (Lazzari, Compans, and Beaujouan 2024). At the regional level, the social context (measured by the share of dissolved partnerships and the extent of the vote for conservative parties) has also been shown to be particularly relevant for explaining the fertility patterns of women aged above 30 in Nordic European countries (Campisi et al. 2022). These findings may give support to the idea that the spread of new demographic behaviors is partially driven by shifts in values and norms, as posited by the Second Demographic Transition theory (Lesthaeghe 1995; Van de Kaa 1987). However, similar aspects were found to be poorly associated with fertility levels over age 35 in European regions in 2018, compared to economic-related factors (Riederer and Beaujouan 2024).

The geographical diffusion of family-related behaviors

While contextual factors may enable or hinder the rise and spread of late fertility in Europe, little attention has been given to geographic mechanisms. Yet, geographic diffusion processes have been widely studied and validated in explaining other aspects of family change, spanning historic fertility transition (Brée and Doignon 2022; Goldstein and Klüsener 2014), contemporary low fertility rates (Vitali and Billari 2017; Wu et al. 2022) and cohabitation (Vitali et al. 2015). All of these studies are grounded in spatial econometric analysis and show that new behaviors spread geographically among adjacent areas rather than occurring randomly in space and time.

The underlying explanations for the spread of a new behavior rely on processes of social influence and social learning at both the individual and aggregate levels (Bongaarts and Watkins 1996; Costa 2015; Montgomery and Casterline 1996; Rogers 1983). Channels facilitating the transmission include kinship ties, social networks, and the pervasive influence of mass media. For instance, observing trends in one's immediate environment can provide insights into the costs and rewards of childbearing (Balbo and Barban 2014; Bernardi 2003) and, in turn, directly influence individuals' reproductive decisions. Positive media portrayal of assisted reproductive technologies and mothers in their forties may also alleviate potential concerns regarding late childbearing and encourage individuals to delay childbearing themselves (Lahad and Madsen 2016; Mills, Lavender, and Lavender 2015). Furthermore, the observed value shift in favor of late parenthood across all social strata (Lazzari et al. 2024) may also have influenced the adoption of late fertility behaviors.

Space is, inherently, one key dimension of transmission processes, as pioneered by Hägerstrand (1968) according to whom the spread of new phenomena reflects the spatial structure of social networks. His theory shows how diffusion initiates slowly, gains momentum with increasing adoption, and eventually decelerates upon reaching saturation. Within the realm of diffusion geography, scholars have defined two specific patterns of spread: contagious and hierarchical diffusion (Morrill, Gaile, and Thrall 2020; Sant-Julien 2007). Hierarchical diffusion involves the spread of a phenomenon along specifically organised channels of communication or hierarchical structures. This form of diffusion may occur from higher educated groups to less educated groups or from big cities to small towns, often bypassing intermediate locations, while following established pathways of influence and communication. On the other hand, contagious diffusion hinges on geographic proximity, succinctly captured by Tobler (1970:236) "everything is related to everything else, but near things are more related than distant things". In this paradigm, contact probabilities decrease with distance rather than following hierarchies. For example, influence by geographic proximity may stem from shared policies, cultural affinities or economic integration. Among empirical studies of other family-related changes, contagion diffusion has been tested and verified (e.g. Brée and Doignon 2022;

Vitali and Billari 2017). Yet, the existence of one diffusion channel does not rule out the existence of the other. For instance, Doignon et al. (2020) descriptively show that non-marital cohabitation has diffused across both dimensions in Belgium, indicating that both channels can contribute to the spread of a phenomenon. For late fertility, evidence points towards a hierarchical spread, with larger urban centers exhibiting higher rates, which could potentially spread to other regions (Riederer and Beaujouan 2024; Šprocha and Fitalová 2022). Yet, the geographic mechanism of the spread of late fertility remains untested.

Hypothesis

Building on previous findings, we propose that late fertility behavior across Europe, characterized by its wide variability both between and within countries (Beaujouan 2020b; Riederer and Beaujouan 2024), spreads through specific diffusion channels. The empirical literature points towards capital regions pioneering this upward trend (Buelens 2021; Riederer and Beaujouan 2024; Šprocha and Fitalová 2022). Yet, we contend that late fertility is not exclusively an urban phenomenon as adverse economic conditions, which can often be more severe in rural areas, may also lead to higher rates of late fertility (Beaujouan 2020a; Skirbekk 2022:200).

Thus, we hypothesize a multifaceted diffusion process that operates beyond the urban hierarchy. We posit that the spread of late fertility is driven by geographic proximity, which may include but is not limited to the proximity to urban areas. Societies in geographically proximate regions may be more likely to share similar resources and engage in social, economic and cultural interactions, fostering the diffusion of behavioral patterns. Thus, our main hypothesis is formulated follows:

> *Contagion hypothesis* Late childbearing behavior in a given region in the current period (t) is influenced by the behaviors observed in nearby regions earlier ($t-1$)

We anticipate that the strength of the contagion effect will diminish as the geographic distance between regions increases. Furthermore, we evaluate its influence by controlling for relevant contextual factors likely to drive late fertility rates, such as changing economies and labor markets. Despite changes in socioeconomic factors, we believe that contagion diffusion processes will remain apparent, representing a new dimension in understanding how late fertility behavior spreads as societies are connected and develop.

3. ECONOMETRIC FRAMEWORK

Data

The primary data source for this study is the Eurostat database, which provides regional statistics on demographics, education, labor markets, and the economy. This database harmonizes regional data from national statistical authorities, enabling consistent cross-country comparisons. To fill data gaps, we supplement it with data from national statistical offices[2] and incorporate one economic metric from the European Spatial Planning Observation Network (ESPON). The regional classification of all employed data

[2] Regional data was obtained from Statistics Belgium, the Statistical Office of the Free State of Saxony, Statistics Poland, and the Statistical Office of the Republic of Slovenia.

adheres to the *Nomenclature des Unités territoriales statistiques* (NUTS) 2 level, which delineates the economic territory of Europe into units suitable for socioeconomic analysis. This classification provides the most granular information available for age-specific fertility rates, offering a sufficiently lengthy time series to study the propagation of late fertility behavior across space. Additionally, the NUTS 2 level aligns with our research objectives, as it represents basic regions for implementing regional policies, including those qualifying for EU cohesion policy support (Eurostat 2018).

Our dependent variable measures the contribution of late fertility rates to total fertility during the current time period (t). It is operationalized as the sum of age-specific fertility rates of women between ages 35 and 49 divided by the total fertility rate (TFR) of a region (Eurostat online data code: demo_r_frate2). In 2018, data on very late fertility rates (ages 45-49) are unavailable for German regions. We address this issue by employing linear interpolation, under the assumption that fertility rates converge to zero beyond age 50. This is grounded in the decreasing biological likelihood of conception (Leridon 2008) and the reduced effectiveness of reproductive technologies in this age group (Malizia, Hacker, and Penzias 2009; Yeh et al. 2014). Additionally, we test a more restrictive measure of late fertility (age range of 40-49) for our dependent variable.

The focus of our analysis is on understanding the geographic mechanism behind the spread of late fertility behavior over time. We measure its diffusion using the contribution of late fertility rates to total fertility in geographically nearby areas at the previous time period $(t - 1)$. In our main analysis, we define such neighborhood as regions sharing common borders. As this definition is central to the inference in our analysis, alternative definitions are discussed in the subsequent section.

To isolate the spatiotemporal diffusion mechanism, we control for various observable contextual factors known to influence late fertility rates. Socioeconomic factors first encompass the share of women with tertiary education (ages 25-64), categorized according to the International Standard Classification of Education (ISCED 2011 levels 5-8, and up to 2013 ISCED 1997 levels 5-6). We further control for the share of young people (ages 15-29) who are not employed (unemployed or inactive according to the International Labour Organization), and who have not participated in any education or training (neither formal nor non-formal) in the four weeks preceding the EU-Labor Force Survey (NEET indicator). In addition, our models also consider the gross domestic product (GDP) measured in purchasing power parities (PPS), and population density, which is calculated by dividing the population as of January 1 by the area of the region in square kilometers[3].

Our sample is a balanced panel comprises 193 regions at NUTS 2 level within 18 European countries, spanning the years 2006 to 2018. Table 1 presents its summary statistics. All data adhere to the 2016 amendment of the NUTS 2 classification (Commission Regulation (EU) 2016/2066), which categorizes geographic territories with an average population size ranging from 800,000 to 3 million (Eurostat 2018). We combine the two Polish regions Warszawski stoleczny (NUTS code PL91) and Mazowiecki regionalny (PL92) due to classification issues over time. For this artificially combined region, we either sum (e.g.

[3] Eurostat online data codes: edat_lfse_04, edat_lfse_22 and demo_r_d2jan; ESPON online data code: GDP_PPSperInhabitant.

population count) or take the mean (e.g. % women with tertiary education) depending on the variable[4]. Furthermore, we exclude geographically isolated regions (such as Åland in Finland or Illes Balears in Spain) as a prerequisite for spatial econometric analysis. Table A1 in the Appendix provides an overview of the regional divisions. Despite using supplementary data from national statistical offices, 0.2% of all observation points are missing. To achieve a balanced panel which is a prerequisite for our analysis, we have predicted missing values by selecting the best-fit autoregressive integrated moving average models based on the AIC value.

TABLE 1 Summary statistics

	2018				$\Delta_{(\mathbf{2006,2018})}$
	Mean	***SD***	***Min***	***Max***	
% contribution late fertility 35-49	22.75	5.97	13.10	38.07	+ 37.05%
% contribution late fertility 40-49	4.37	1.63	2.00	9.10	+ 66.16%
% women with tertiary education	33.24	10.13	16.20	63.90	+ 48.13%
% NEET	11.16	5.18	4.50	36.20	− 10.29%
GDP	30,780.83	10,260.03	13,900.00	79,200.00	+ 26.67%
Population density	325.06	783.84	3.17	7,706.88	+ 6.56%
N	193 regions at NUTS 2 level in 18 countries				

Sources Eurostat (online data codes: demo_r_frate2, edat_lfse_04, edat_lfse_22 and demo_r_d2jan), ESPON (online data code: GDP_PPSperInhabitant) and national statistical offices.

Methods

We employ a dynamic spatial Durbin model (SDM) to analyze the geographic mechanism of the rise and spread of late fertility across Europe. This model stands as one of the latest advancements in spatial econometric research and has only recently been implemented in statistical software environments (Bivand, Millo, and Piras 2021; Elhorst 2012; Simonovska 2024). By integrating both spatial and dynamic components, the SDM offers a sophisticated framework for testing our hypothesis.

The model selection is driven by both theoretical and statistical considerations. First, our study is grounded in the observation that late childbearing behavior exhibits significant spatial dependence: regions with high (low) contributions of late fertility tend to be surrounded by similar regions. This is evidenced by significant and positive Moran's I statistics (a measure of spatial autocorrelation) across each year of observation and different neighborhood structures. While a simpler spatial autoregressive (SAR)-type

[4] For the combined Polish capital region, the NEET indicator is missing for the period between 2006 and 2012. We address this gap by incorporating the distribution of cities derived from NEET data disaggregated by the degree of urbanization (Eurostat online data code: edat_lfse_29).

model would also allow us to consider such dependence, it risks producing biased estimates and inefficient inference if there is additional spatial autocorrelation in the explanatory variables (Elhorst 2010:14). In our sample, statistical tests confirm such existence (see Table A2 in the Appendix), underscoring the necessity to control for potential spillover effects from predictors. Additionally, Bayesian log-marginal posterior probabilities support the superiority of SDM over other spatial model types (LeSage 2014; LeSage and Parent 2007).

Another strength of the SDM lies in its capability to account for local and global spatial spillover effects (Anselin 2003; Elhorst 2014). Local spillovers occur when regions are connected, while global spillovers can occur irrespective of regional connections. In the case of the latter, changes are disseminated through the spatial multiplier matrix[5] to other regions. For late fertility, such effects matters, as also a multi-channel spread may occur, facilitated by mass media, where networks easily extend beyond geographic boundaries. A positive media portrayal of assisted reproductive technologies and mothers in their forties, for instance, may alleviate potential concerns regarding late childbearing (Mills et al. 2015).

Lastly, previous studies have already highlighted the effectiveness of SDMs in studying diffusion processes (Brée and Doignon 2022; Ciccarelli and Elhorst 2018; Vitali et al. 2015; Vitali and Billari 2017). Diverging from the conventional static models prevalent in all but one of these studies (Ciccarelli and Elhorst 2018), we opted for a dynamic version. Instead of attributing the variation in late childbearing at the current period (t) to late fertility in nearby areas within the same period, we consider the previous time period ($t-1$). Such a temporal lag acknowledges spatial diffusion as a phenomenon influenced by historical behaviors, in line with the conceptualization of Costa et. al (2021) and Ciccarelli and Elhorst (2018). Nevertheless, we also show static model estimations alongside our preferred (dynamic) specification to show their differences.

Our main model specification, i.e. a dynamic SDM, reads as follows:

$$Y_t = \tau Y_{t-1} + \delta W Y_t + \eta W Y_{t-1} + X_t \beta + W X_t \theta + \delta + \varepsilon_t \tag{1}$$

where Y_t is an $N \times 1$ vector that represents the contribution of late fertility rates to the total fertility rate in a region at time t. X_t is a $N \times K$ matrix of endogenous variables, where N represents the number of regions being studied and K represents the number of variables. The subscript $t-1$ indicates a serial lag, while a multiplication by the $N \times N$ connectivity matrix W denotes a spatial lag. The parameter of primary interest is η, capturing spatiotemporal diffusion. δ is the spatial dependence parameter describing present spatial interactions and τ is the autoregressive time dependence parameter. The $K \times 1$ vectors β and θ correspond to the reactions of Y_t to the explanatory variables X_t and their spatial lags WX_t. Furthermore, we incorporate regional fixed effects, denoted by δ, to mitigate endogeneity concerns by controlling for unobserved heterogeneity (e.g. childcare arrangements) at the regional level. Lastly, ε_t denotes the error term that consists of i.i.d. disturbance terms, which have zero mean and finite variance σ^2. All models are

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[5] The spatial multiplier matrix is given by $(I - \delta W)^{-1}$. A detailed derivation of the dynamic spatial panel model can be found in Lee and Yu (2016) and Elhorst (2012).

estimated by the Maximum Likelihood estimator using the *SDPDmod* package in the software environment R (Simonovska 2024).

Neighborhood connectivity is operationalized through a row-normalized binary contiguity matrix, denoted as W^1. In this matrix, adjacency between regions is represented by $w_{i,j}^1 > 0$ for neighboring regions i and j, and $w_{i,j}^1 = 0$ otherwise. Conventionally, the self-neighbor relation is ruled out, so that diagonal elements are all zero, $w_{i,\mathrm{i}}^1 = 0$. This connectivity is frequently employed in modeling diffusion processes (Brée and Doignon 2022; Ciccarelli and Elhorst 2018; Vitali et al. 2015; Vitali and Billari 2017) and fits our contagion hypothesis.

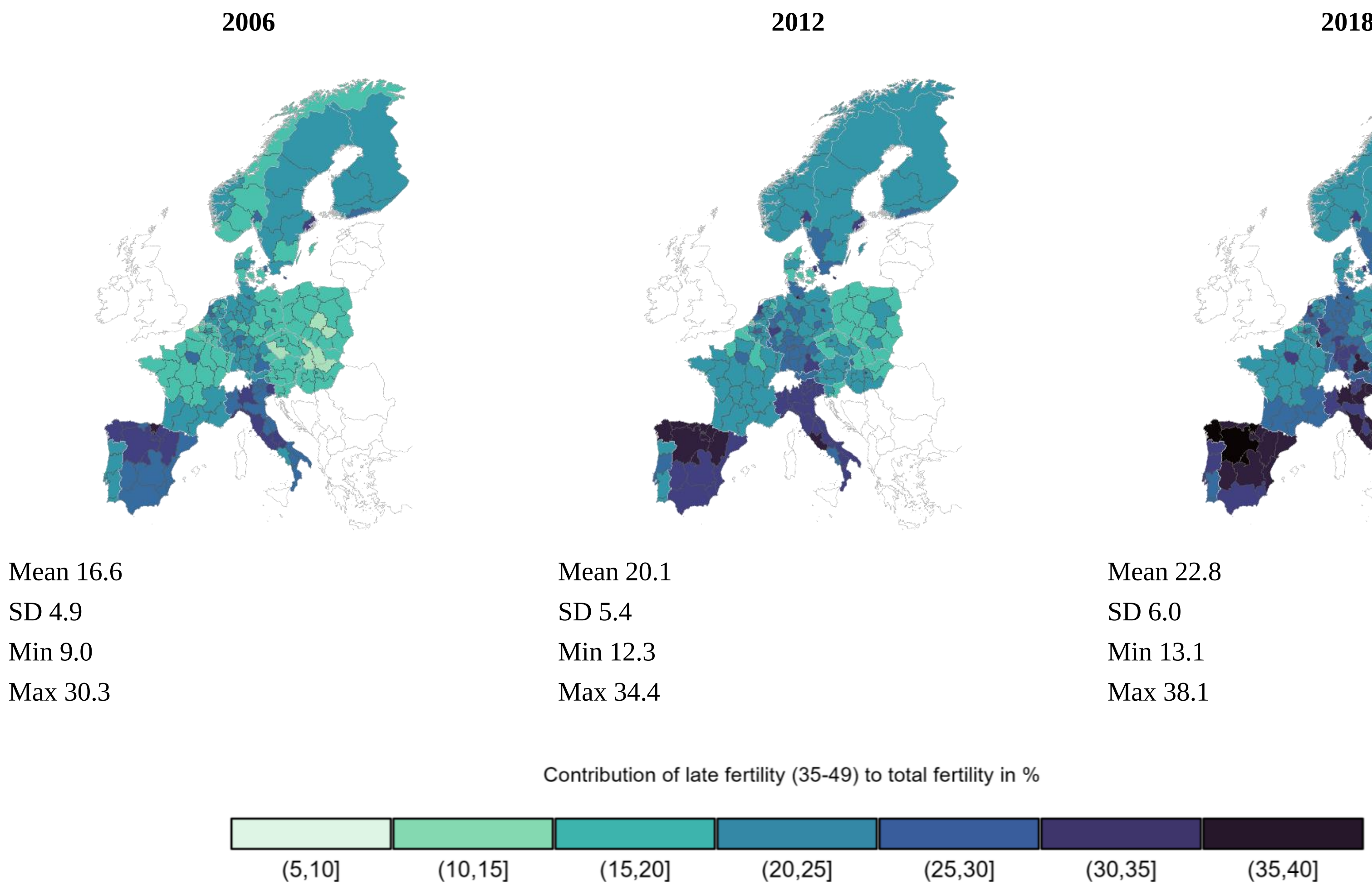
In spatial analysis, inference is conditioned on the spatial weights matrix (Anselin 2013; Halleck Vega and Elhorst 2015). The theory does not provide an explanation for the true geographic data generating process underlying the rise and spread of late fertility. Thus, we also test alternative neighborhood structures to provide a more comprehensive understanding of the response to changes in connectivity. Alternatives include higher-order contiguity and distance-based matrices. Expanding beyond our primary choice of W^1 we also consider a second-order contiguity matrix denoted as W^2. This connectivity also includes indirect connections through shared neighbors: i.e., for regions i and j, $w_{i,j}^2 > 0$ if they share at least one common neighbor, otherwise $w_{i,j}^2 = 0$. Furthermore, we explore two types of distance-based matrices that utilize the geodesic distance between centroids of regions (Karney 2013). Firstly, the inverse-distance matrix, denoted as W^{inv}, which adjusts regions' weights based on the decay of distance: $w_{i,j}^{inv} = d_{i,j}^{-\varphi}$, where the parameter φ determines the speed of decay. A benchmark of $\varphi = 1$ indicates that weights are inversely proportional to distance, while higher φ values indicate faster decay. In our analyses, we test for slight ($\varphi = 2$) and quicker ($\varphi = 4$) decay. Lastly, we consider k-nearest neighbors spatial matrices W^{knn} that focus on a predefined number of neighbors (knn$= 4$ and knn$= 8$), starting with those closest in distance to centroids.

4. RESULTS

Spatiotemporal patterns

Before empirically testing our hypothesis, we present the evolution of late fertility across European regions from 2006 to 2018. Figure 1 shows a series of diachronic maps that depict how much late fertility rates (ages 35-49) contribute to overall fertility levels in different regions, with darker hues indicating a greater contribution. Over the study period, the mean contribution increased by roughly 37%, jumping from 16.6 in 2006 to 22.8 in 2018. Initially, late fertility was not widespread across Europe in 2006, with more than two-thirds of the regions having contributions between 10-20%. Only a select few regions exhibited higher rates, primarily in Southern Europe and major urban areas. The maps from 2012 and 2018 reveal consistent spatial distribution trends but highlight the significant increase in late fertility. By 2018, over half of all regions had late fertility contributions exceeding 20%, and even 13.3% of regions had contributions above 30%.

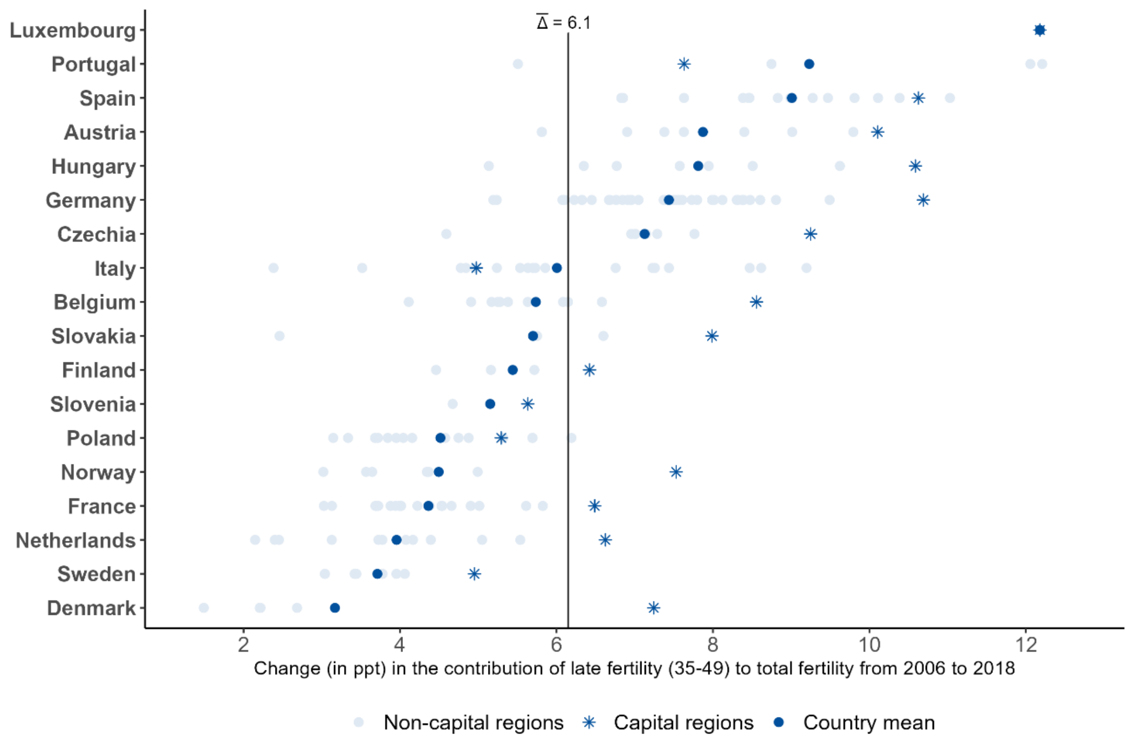
FIGURE 1 Spatial trend of late fertility (NUTS 2 level)



Sources Eurostat (online data code: demo_r_frate2) and national statistical offices.

Spatial heterogeneity in the adoption of late fertility behavior is evident throughout the observation period. As depicted in Figure 1, an analysis at the country level overlooks clear within-country patterns. For instance, in 2006, the Spanish region of País Vasco that is located at the Western end of the Pyrenees recorded the highest contribution at 30.3% across all European regions. However, within Spain itself, not all of the regions mirrored such high levels. Andalucía, located at the opposite end, had the lowest contribution within the country, at 21.2%. The Spanish overall contribution of 24.9% masks such diversity. Similar spatial heterogeneity is observable across all other countries. Over time, we can even observe a widening dispersion within almost all countries (except for Italy), underscoring the increasing relevance of subnational differences.

FIGURE 2 Temporal trend of late fertility (NUTS 2 level)

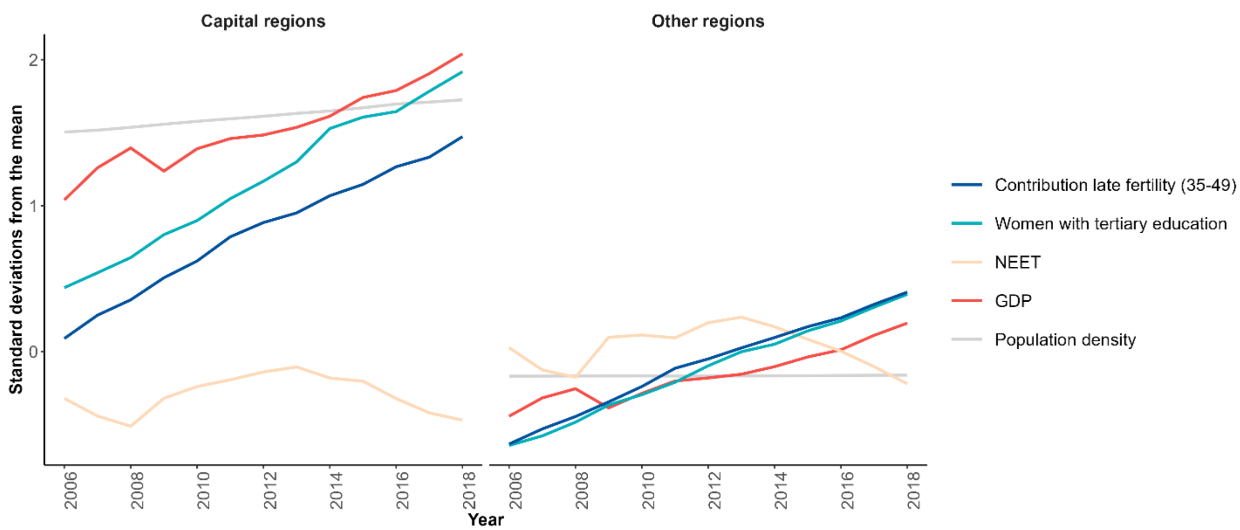


Sources Eurostat (online data code: demo_r_frate2) and national statistical offices.

The distribution appears to follow geographic proximity, with regions sharing similar levels often being in close proximity to each other. This pattern is exemplary for País Vasco Vasco where adjacent areas exhibit increasingly similar high shares across all maps. Likewise, once the Spanish capital region Comunidad de Madrid gains momentum, regions closeby also reach higher levels (see 2012 and 2018). In most cases, such a tendency of geographic clustering does not halt at political boundaries. The case of Spain stands as one of the few exceptions, where we notice that the border with France seems to somewhat slow down the adoption of late fertility behavior. However, for most other borders, such a sharp discontinuity is not observable. Instead, the spread often transcends national borders, as for example apparent in the Danube macro region where national borders seem to be less influential. The transcending influence of geographic proximity is affirmed by statistical tests, with a significant and positive Moran's I statistic (a measure of spatial autocorrelation) across the years, ranking at 0.7 in 2018, 0.6 in 2012, and 0.7 in 2006. Given that not all regions exhibit increased late fertility behavior simultaneously, this pattern of geographical clustering may imply that diffusion has also occurred along this dimension in a contagious manner, from forerunning regions to nearby ones.

Despite late fertility becoming an increasingly prevalent trend, not all regions changed at the same pace. Figure 2 depicts the absolute change in the contribution of late fertility to total fertility levels over our observation. Each dot on the graph represents a region, with darker dots indicating the mean value of all regions within a country and stars denoting the country's capital region. It is striking to observe that every single region recorded an increase between 2006 and 2018 – some to such an extent that they may not have reached their limits. This rise has been greater in capital regions (despite already exhibiting high rates) in most countries (except for Italy, Poland, Portugal and Spain) widening the gap with non-capital regions. Thus, capital regions do not slow down but rather set themselves further apart from their country counterparts. As a result, they often occupy a forerunning position - a factor that could potentially drive contagious diffusion patterns, if found to be relevant.

FIGURE 3 Evolution of key socioeconomic indicators between 2006 and 2018 (standard deviations from the mean)



Notes A year's standard deviation is equal to zero when its value is equal to the mean across all years and regions.

Sources Eurostat (online data codes: demo_r_frate2, edat_lfse_04, edat_lfse and demo_r_d2jan), ESPON (online data code: GDP_PPSperInhabitant) and national statistical offices.

The differences in increases may be explained by greater shifts in socioeconomic features. Such factors have proven to greatly influence late fertility behavior, as discussed in the background section (see "Factors explaining geographical differences in late fertility"). For instance, País Vasco (i.e. the region with the highest contribution in 2006) is also the second biggest economy as measured in GDP in PPS after the capital. Its upsurge in economic prosperity might partially account for the heightened rates that have surpassed those of Madrid. Indeed, we observe that overall trends in economic context align with increases in late fertility behavior. Figure 3 depicts them, differentiating between capital and non-capital regions. Despite notable differences in their levels, there are similarities in terms of general trends across both types of regions. Particularly noteworthy is the parallel trend observed between late fertility and the proportion of women with tertiary education since 2006 in capital regions, and since 2012 in other regions. Despite these indicators following nearly identical paths, their correlation coefficient remains relatively low at 0.16 in the case of non-capital regions and 0.40 in capital regions. Similarly, GDP displays an increasing trend, albeit with a decline during the recession period. A potential downturn in economic performance, impacting youth employment and educational opportunities, is discernible during this period, which may be reflected in the share of NEET. Lastly, population density exhibits minimal variation over time. The correlation between all of the indicators and their spatially lagged counterparts is generally low (see Table A3 in the Appendix), with the notable exception for the share of NEET (0.84).

Overall, we leverage several observations from the descriptive analysis, which are also supported (albeit to a lesser degree) regarding a stricter age threshold of late fertility (see Figures A1 and A2 in the Appendix). First, areas with comparable contributions of late fertility to total fertility tend to be in close proximity, often crossing national borders. Second, there is a discernible trend of capital regions exhibiting higher contributions within their respective countries – positioning them as forerunners. While descriptives point towards the existence of contagion diffusion, visual representation may be biased and merely depict variations in how economic contexts have evolved. Whether the observed increase truly follows a diffusion pattern from forerunning regions to others, facilitated by geographic proximity, rather than occurring randomly across space and time, remains to be tested in empirical models.

Estimation results

In the following, we present our estimation results that control for contextual factors known to impact late fertility rates to isolate the diffusion effect from changes in the socioeconomic environment (e.g. the spread of tertiary education).

Testing our *contagion hypothesis*, Table 2 displays the results for the estimation of both static and dynamic spatial Durbin models. We find that common static conceptualizations of spatial diffusion in the demographic literature (WY_t) tend to overestimate diffusion processes (Column 1). Indeed, our dynamic definition of a contagion process (Column 2), indicated by WY_{t-1}, shows a considerably lower parameter compared to a static one (0.138 vs. 0.784). Holding other factors constant, late childbearing behavior in a specific region and period appears to be significantly influenced by the behavior observed earlier in neighboring regions. This association is even stronger when considering a stricter age threshold of late fertility, defined from age 35 rather than from age 40 (Column 4). In addition to the contagion association, we find spatial clustering in the current period as indicated by the positive association of WY_t, suggesting that regions with similar levels of late fertility continue to cluster together in the current period tend – not necessarily drifting apart. Furthermore, a strong positive association between past fertility rates (Y_{t-1}) and current rates is present, confirming that regions with a higher pace of increase are regions where late fertility was already prevalent.

Table 2 Maximum likelihood estimation results of spatial Durbin models, binary contiguity connectivity matrix, 2006-2018

Dependent variable Contribution of late fertility rates to total fertility				
	Age threshold			
	35-49		40-49	
	(1)	(2)	(3)	(4)
WY_t	0.784***	0.343***	0.747***	0.356***
Y_{t-1}		0.454***		0.373***
WY_{t-1}		0.138***		0.249***
Women with tertiary education	0.052***	0.033***	0.058***	0.028
NEET	-0.011	0.002	0.019	0.001
GDP	0.271***	0.118***	0.373***	0.191***
Population density	0.402***	0.202**	0.802***	0.466***
WWomen with tertiary education	0.061***	0.010	0.082***	-0.023
WNEET	0.044***	0.005	0.064***	0.020
WGDP	-0.113***	-0.119**	-0.163***	-0.117**
WPopulation density	-1.072***	-0.360	-1.297***	-0.779*
Observations	2,509	2,316	2,509	2,316
W	W^1	W^1	W^1	W^1
Region FE	✓	✓	✓	✓
Dynamic		✓		✓
Log. Likelihood	1768.491	2216.42	605.5419	1004.574
R^2 adjusted	0.781	0.914	0.662	0.848

Notes All variables are standardised. All models employ a row-normalized binary contiguity W^1matrix. Significance levels: *p<0.1; **p<0.05; ***p<0.01.

Sources Eurostat (online data codes: demo_r_frate2, edat_lfse_04, edat_lfse_22 and demo_r_d2jan), ESPON (online data code: GDP_PPSperInhabitant) and national statistical offices.

Tables 3 presents how the choice of neighborhood connectivity structure affects the estimation results. We find evidence that the strength of the contagion effect (WY_{t-1}) diminishes with increasing distance between regions. In contrast to our main choice of binary contiguity weights matrix, the use of a secondary contiguity weights matrix (Column 1), where neighbors' neighbors are additionally included, shows that the diffusion effect diminishes with more far-reaching connectivity. Distance-based matrices further support this observation. When testing an even more generous specification where connectivity is not restricted to sharing common borders but generally decreases across the whole cross-section with distance (Columns 2 and 3), we find that the farther and more generous the connectivity, the less likely we are to observe a diffusion process in WY_{t-1}. Only the very restricted distance-based version (Column 3), which emphasizes closer regions, shows similar patterns to the binary contiguity connectivity. We find a similar pattern for k-nearest neighbors specifications (Columns 4 and 5) and conclude that regions closer in proximity tend to exhibit a stronger influence on each other's late fertility behavior in the subsequent period compared to regions that are farther apart. Results for the stricter age threshold support the diminishing effects of distance on diffusion and are available in Table A4 in the Appendix.

Table 3 Maximum Likelihood estimation results of spatial Durbin models, alternative connectivity matrices, 2006-2018

Dependent variable Contribution of late fertility rates (35-49) to total fertility					
	(1)	(2)	(3)	(4)	(5)
WY_t	0.473***	0.527***	0.288***	0.369***	0.461***
Y_{t-1}	0.487***	0.474***	0.469***	0.444***	0.468***
WY_{t-1}	0.007	0.043	0.154***	0.114***	0.026
Observations	2,316	2,316	2,316	2,316	2,316
W	W^2	$W^{inv\varphi 2}$	$W^{inv\varphi 4}$	W^{knn4}	W^{knn8}
Controls	✓	✓	✓	✓	✓
Region FE	✓	✓	✓	✓	✓
Dynamic	✓	✓	✓	✓	✓
Log. Likelihood	2210.416	2214.898	2189.85	2225.991	2233.686
R^2 adjusted	0.914	0.910	0.913	0.914	0.913

Notes All variables are standardised. Controls include women with tertiary education, NEET, GDP, and population density. Models employ different connectivity matrices: row-normalized secondary contiguity matrix W^2, inverse-distance matrices with benchmark value φ equal to 2 $W^{inv\varphi 2}$ or 4 $W^{inv\varphi 4}$, and k-nearest neighbor matrices considering 4 W^{knn4} or 8 neighbors W^{knn8}. Significance levels: *p<0.1; **p<0.05; ***p<0.01.

Sources Eurostat (online data codes: demo_r_frate2, edat_lfse_04, edat_lfse_22 and demo_r_d2jan), ESPON (online data code: GDP_PPSperInhabitant) and national statistical offices.

5. DISCUSSION AND CONCLUSIONS

This paper examines the geographic mechanism underlying the rise of late motherhood across European regions. While previous studies have attributed variations in late fertility rates to contextual factors (e.g. Riederer and Beaujouan 2024), the role of diffusion processes has remained overlooked. Yet, the spread of late childbearing behavior has not occurred randomly across space and time but rather follows a specific geography. Our analysis addresses this gap and employs a dynamic spatial Durbin model to assess the diffusion process in the spatiotemporal patterns of the contribution of births over age 35 to total fertility levels between 2006 and 2018.

Our results present robust evidence of a contagion effect in the spread of late fertility across Europe. This means that late childbearing behavior in a given region is influenced by the behavior observed in neighboring regions earlier. We find this geographic mechanism to persist even after accounting for various socioeconomic factors such as education levels, economic conditions, labor market situations, and urbanization levels. Such a diffusion pattern implies that the transmission of the new behavior occurs from forerunning regions to nearby others – also transcending borders in the process. In our sample, capital regions exhibit the highest rates in almost all of the 18 observed countries throughout the observation period. Thus, they are expected to act as forerunners to a large extent – suggesting contagious diffusion to be accompanied by a strong (but not sole) influence of capitals in driving the considerable surge in late fertility rates across Europe.

In addition, our study underscores the significance of accurately conceptualizing diffusion processes. We find that common static conceptualizations (e.g. Vitali et al. 2015) may overestimate the degree of geographic diffusion. Another critical aspect involves the selection of the connectivity structure. Nearly all studies focusing on identifying diffusion mechanisms impose a singular choice of spatial structure: binary contiguity (e.g. Brée and Doignon 2022). We contend that it is beneficial to explore various connectivity structures, as parameter size and inference heavily relies on such choices. In the case of late fertility diffusion, we find that connectivities that prioritize spatial proximity, such as binary contiguity, with a pronounced distance decay of weights and with a low predefined number of neighbors, are most relevant. They all support our assumption that the strength of the contagion effect will diminish as the geographic distance between regions increases – but parameter size varies.

The findings are in line with theoretical explanations and extend prior literature. In particular, they add to the extensive literature that find diffusion processes to be relevant for understanding family change (e.g. Costa et al. 2021; Doignon et al. 2020; Goldstein and Klüsener 2014; Vitali and Billari 2017). It is argued that individuals and societies learn from and adopt behaviors observed in nearby areas, thereby forming a social diffusion process (Bongaarts and Watkins 1996; Costa 2015; Montgomery and Casterline 1996; Rogers 1983). However, whether such interconnectedness for late fertility is driven by social interactions and social influence remains an open question. The aggregate nature of our data limits our ability to observe the underlying mechanisms driving this diffusion phenomenon, such as the influence of media, social networks, and interpersonal communications. Future research may benefit from integrating individual level data to better understand the specific channels through which late fertility behaviors spread across space. Nonetheless, our results introduce a novel dimension to our understanding of diverse late fertility rates across Europe. In addition to the strong impact of socioeconomic contextual factors, geographical patterns adhere to a contagion diffusion process. There appears to be a potential amplification exerted by capital regions, corroborating fragments of previous evidence indicating that late fertility is notably prevalent in urban areas (Riederer and Beaujouan 2024) and accompanied by a more pronounced increase (Šprocha and Fitalová 2022).

Our study is not without limitations. First, our findings may be susceptible to the modifiable areal unit problem (MAUP), a form of ecological fallacy (Openshaw 1984), where grouping data into various scales or boundaries can affect analytical outcomes. According to the European Spatial Planning Observation Network (2006:134), our level of aggregation (NUTS 2) is less susceptible to MAUP compared to NUTS 3, due to a greater coherence in combining urban, peri-urban, and rural territories at the NUTS 2 level. In contrast, NUTS 3 units often mix different geographical units or isolate them in separate units, posing challenges for analyses. In addition, Riederer and Beaujouan (2024) demonstrate that there are no significant disparities in late fertility rates between the two aggregation levels.

Second, we acknowledge that the causal interpretation of the spatiotemporal diffusion effect is limited. Despite our efforts to control for various contextual factors known to influence late fertility differentials, our model does not encompass all variables impacting late fertility decisions. Cultural factors like family and reproduction norms, or structural ones like access and quality of childcare services, may impact fertility decisions but could not be accounted for in our analysis due to the lack of regional data over time. For example, Wood and Neels (2019) demonstrate a positive effect of formal childcare services on the transition to parenthood by exploiting Belgian regional data. This omission may introduce residual confounding, which we aim to mitigate by incorporating regional fixed effects.

Third, we cannot distinguish the parity of fertility rates. Although it is possible that, in some regions, late births occur more often within large families, the average family size has considerably reduced over the studied period and countries and births occurring from age 35 are increasingly first or second children (Beaujouan and Sobotka 2019). Whether the diffusion of births over age 35 reflects more the tendency to postpone and catch up on the delay of first motherhood than family enlargement is worth further research. Related to that, our measure focuses on realized outcomes but does not indicate whether births are increasingly intended at advanced ages. Such a rise in fertility intentions over age 35 has been documented for Austria (Beaujouan 2022) and may apply to other areas. This may prompt questions whether our measure already captures inequalities in knowledge, resources, or access to fertility treatment, as late fertility trends have been accompanied by a rise in assisted reproduction activity (EIM et al. 2023). Yet, it is likely not the case as assisted reproductive technology without egg donation from a younger female donor to an older recipient cannot fully compensate for the decline of fecundity with age (Leridon 2008), hence poorly contributing to the rise in late fertility rates in Europe (Kocourkova, Burcin, and Kucera 2014).Despite these limitations, our study emphasizes that late fertility has become increasingly widespread at the subnational level, not least due to the joint influence of socioeconomic transformations and diffusion processes. With no sign of this trend plateauing, even in regions where high levels have been already reached, diffusion processes may even result in a higher prevalence in the upcoming years. This shift carries significant implications that span health and socioeconomic realms. At the micro level, one can wonder if and when biological limits for reproduction would be reached. As more women have children later in life, more are likely to encounter biological constraints or infertility issues. Consequently, the demand for assisted reproductive technology is expected to rise. In this context, the regional context is likely to be crucial as proximity to a fertility clinic affects ART accessibility (Jones, Peri-Rotem, and Mountford-Zimdars 2023; Lazzari, Baffour, and Chambers 2022; Mackay, Taylor, and Glass 2023), and reimbursement policies for infertility treatments can vary between regions (e.g. in Italy, Spain or Poland). Furthermore, at the macro level, late (and low) fertility rates will likely continue shaping population aging and economic dependencies (Bloom, Kuhn, and Prettner 2024; Gietel-Basten, Rotkirch, and Sobotka 2022). All of these aspects further underscore the necessity for discussions on how societies can adapt to the changing demography. For European countries, late fertility developments present a shared challenge, necessitating a comprehensive dialogue to formulate proactive policies supporting women in their reproductive decisions and addressing both the constraints and opportunities associated with late childbearing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

APPENDIX

TABLE A1 Regional division

ISO code	Country name	Region codes	Count
AT	Austria	AT11, AT12, AT13, AT21, AT22, AT31, AT32, AT33, AT34	9
BE	Belgium	BE10, BE21, BE22, BE23, BE24, BE25, BE31, BE32, BE33, BE34, BE35	11
CZ	Czechia	CZ01, CZ02, CZ03, CZ04, CZ05, CZ06, CZ07, CZ08	8
DE	Germany	DE11, DE12, DE13, DE14, DE21, DE22, DE23, DE24, DE25, DE26, DE27, DE30, DE40, DE50, DE60, DE71, DE72, DE73, DE80, DE91, DE92, DE93, DE94, DEA1, DEA2, DEA3, DEA4, DEA5, DEB1, DEB2, DEB3, DEC0, DED2, DED4, DED5, DEE0, DEF0, DEG0	38
DK	Denmark	DK01, DK02, DK03, DK04, DK05	5
ES	Spain	ES11, ES12, ES13, ES21, ES22, ES23, ES24, ES30, ES41, ES42, ES43, ES51, ES52, ES61, ES62	15
FI	Finland	FI19, FI1B, FI1C, FI1D	4
FR	France	FR10, FRB0, FRC1, FRC2, FRD1, FRD2, FRE1, FRE2, FRF1, FRF2, FRF3, FRG0, FRH0, FRI1, FRI2, FRI3, FRJ1, FRJ2, FRK1, FRK2, FRL0	21
HU	Hungary	HU11, HU12, HU21, HU22, HU23, HU31, HU32, HU33	8
IT	Italy	ITC1, ITC2, ITC3, ITC4, ITF1, ITF2, ITF3, ITF4, ITF5, ITF6, ITG1, ITG2, ITH1, ITH2, ITH3, ITH4, ITH5, ITI1, ITI2, ITI3, ITI4	19
LU	Luxembourg	LU00	1
NL	Netherlands	NL11, NL12, NL13, NL21, NL22, NL23, NL31, NL32, NL33, NL34, NL41, NL42	12
NO	Norway	NO01, NO02, NO03, NO04, NO05, NO06, NO07	7

PL	Poland	PL21, PL22, PL41, PL42, PL43, PL51, PL52, PL61, PL62, PL63, PL71, PL72, PL81, PL82, PL84, PL91|PL92	16
PT	Portugal	PT11, PT15, PT16, PT17, PT18	5
SE	Sweden	SE11, SE12, SE21, SE22, SE23, SE31, SE32, SE33	8
SI	Slovenia	SI03, SI04	2
SK	Slovakia	SK01, SK02, SK03, SK04	4
18 countries		193 regions at NUTS 2 level	

Notes The NUTS 2 region codes refer to the NUTS 2016 classification (Commission Regulation (EU) 2016/2066). Geographically isolated regions (such as Åland in Finland or Illes Balears in Spain) are excluded. The two Polish regions PL91 and PL92 are combined into a single region because of inconsistencies in their classification over time.

TABLE A2 Results of Moran's test for spatial autocorrelation

	Connectivity			
	Contiguity			
	W^1		W^2	
% contribution late fertility 35-49	0.66	$< 2.2e-16$	0.55	$< 2.2e-16$
% contribution late fertility 40-49	0.64	$< 2.2e-16$	0.53	$< 2.2e-16$
% women with tertiary education	0.60	$< 2.2e-16$	0.51	$< 2.2e-16$
% NEET	0.70	$< 2.2e-16$	0.64	$< 2.2e-16$
GDP	0.32	$1.386e-11$	0.27	$< 2.2e-16$
Population density	0.03	0.195	0.02	0.189
Average number of links	4.81		14.11	
% non-zero weights	2.49		7.31	
N	193 regions at NUTS 2 level			

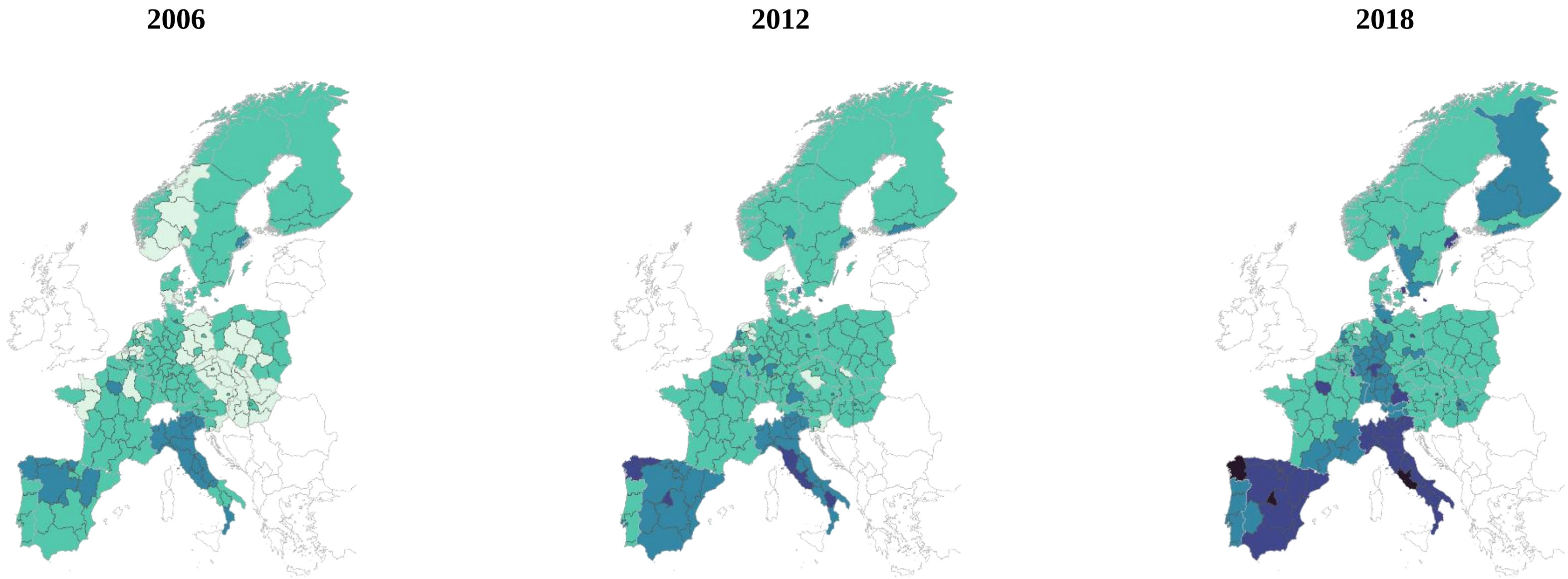
Notes The year of reference is 2018. All tests reject the null of no spatial autocorrelation in the dependent variable % late fertility for any of the considered connectivity matrices.

TABLE A3 Correlation matrix

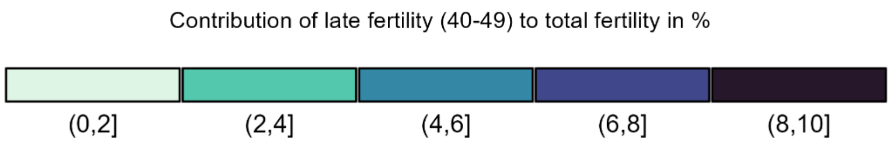
	Women Tertiary	NEET	GDP	Pop Density	W Women Tertiary	W NEET	W GDP	W Pop Density
WomenTertiary	1							
NEET	-0.27	1						
GDP	0.42	-0.49	1					
PopDensity	0.19	0.02	0.42	1				
WWomenTertiary	0.79	-0.19	0.19	0.05	1			
WNEET	-0.22	0.84	-0.46	-0.13	-0.26	1		
WGDP	0.18	-0.5	0.56	0.03	0.34	-0.6	1	
WPopDensity	-0.08	-0.17	0.11	0.14	0	-0.13	0.32	1

Notes W refers to a row-normalized binary contiguity matrix *(*W^1).

FIGURE A1 Spatial trend of late fertility (NUTS 2 level)

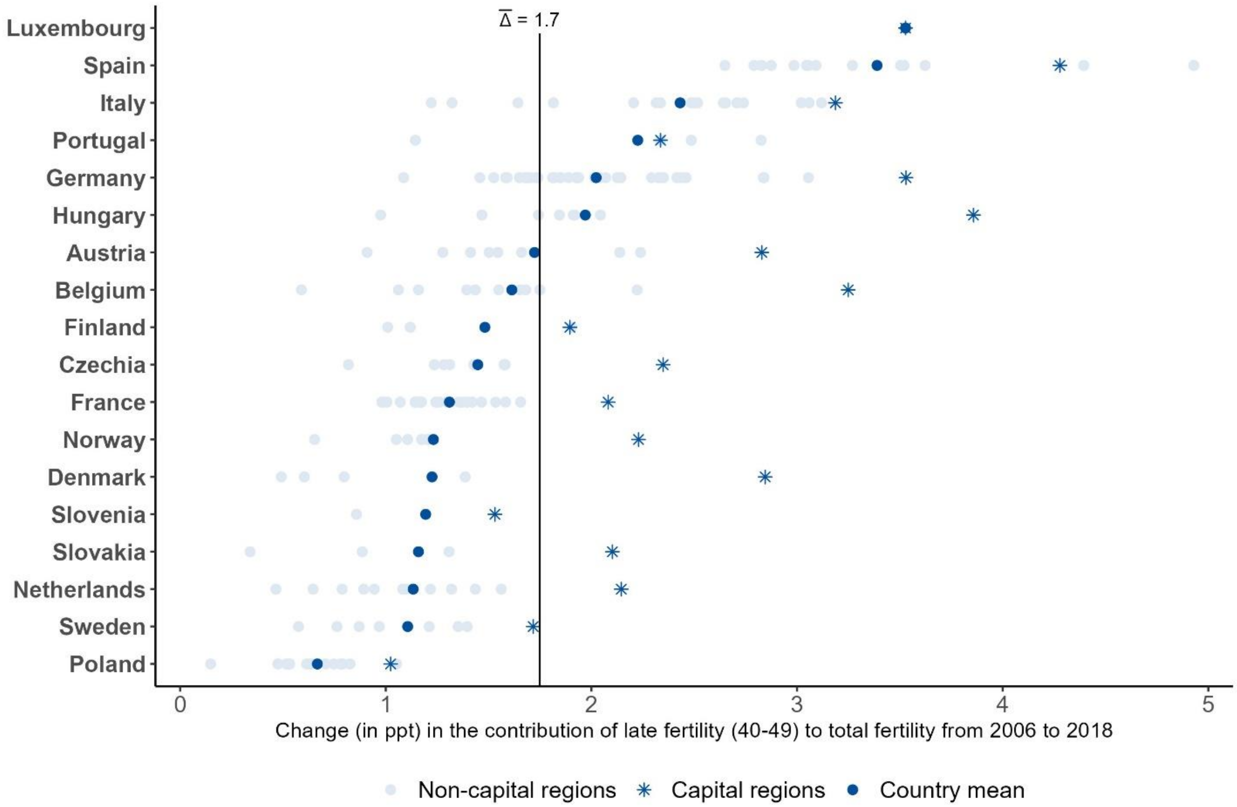


2006	2012	2018
Mean 2.63	Mean 3.48	Mean 4.37
SD 0.96	SD 1.29	SD 1.63
Min 1.07	Min 1.63	Min 2.00
Max 5.29	Max 7.15	Max 9.10



Sources Eurostat (online data code: demo_r_frate2) and national statistical offices.

FIGURE A2 Temporal trend of late fertility (NUTS 2 level)



Sources Eurostat (online data code: demo_r_frate2) and national statistical offices.

Table A4 Maximum likelihood estimation results of spatial Durbin models, alternative connectivity matrices, 2006-2018

Dependent variable Contribution of late fertility rates (40-49) to total fertility					
	(1)	(2)	(3)	(4)	(5)
WY_t	0.529***	0.549***	0.315***	0.358***	0.491***
Y_{t-1}	0.378***	0.381***	0.423***	0.377***	0.362***
WY_{t-1}	0.112**	0.236***	0.201***	0.221***	0.137***
Observations	2,316	2,316	2,316	2,316	2,316
W	W^2	$W^{inv\varphi 2}$	$W^{inv\varphi 4}$	W^{knn4}	W^{knn8}
Controls	✓	✓	✓	✓	✓
Region FE	✓	✓	✓	✓	✓
Dynamic	✓	✓	✓	✓	✓
Log. Likelihood	1020.784	1011.924	960.0229	1005.188	1047.136
R^2 adjusted	0.849	0.842	0.841	0.846	0.848

Notes All variables are standardised. Controls include women with tertiary education, NEET, GDP, and population density. Models employ different connectivity matrices: row-normalized secondary contiguity matrix W^2, inverse-distance matrices with benchmark value φ equal to 2 $W^{inv\varphi 2}$ or 4 $W^{inv\varphi 4}$, and k-nearest neighbor matrices considering 4 W^{knn4} or 8 neighbors W^{knn8}. Significance levels: *p<0.1; **p<0.05; ***p<0.01.

Sources Eurostat (online data codes: demo_r_frate2, edat_lfse_04, edat_lfse_22 and demo_r_d2jan), ESPON (online data code: GDP_PPSperInhabitant) and national statistical offices.

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