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The Diffusion of Late Fertility Across European Regions (2006–2018)

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Abstract

The rise in late fertility has emerged as a landmark trend in high-income countries in recent decades. Yet, its spread has been geographically uneven, which has largely been attributed to socioeconomic contextual factors. Our study introduces a new perspective: the role of spatial diffusion processes. We exploit the regional variation in the increase in the contribution of late fertility rates to total fertility to assess whether a region follows the behaviour of nearby regions in preceding periods. To test this, we use a comprehensive panel of 193 regions across 18 European countries and utilise a dynamic spatial Durbin model that captures both temporal and spatial interdependencies. After accounting for socioeconomic factors known to affect late fertility rates, such as the tertiarisation of education or changes in the opportunity structure of the labour market, we still find a significant association between geographic proximity and the rise in late fertility across European regions. This underlines the deep interconnectedness within and across contemporary societies. Thus, beyond socioeconomic transformations, our research provides empirical evidence that diffusion processes have contributed to the spread of late births across the continent, and will likely continue to shape future fertility trends.

Keywords

diffusion; dynamic panel analysis; fertility timing; late motherhood; postponement; spatial dependence

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Conflicts of Interest
The authors declare no conflicts of interest.

1 Introduction

Reproductive patterns in high-income countries have increasingly shifted towards later ages (Billari et al. 2007; Prioux 2005). By 2018, about one-fifth of births in Europe were to women aged 35 and older (Riederer and Beaujouan 2024). Despite this general trend, significant differences in the prevalence of late fertility exist both *between* (Beaujouan 2020; Prioux 2005) and *within* countries (Riederer and Beaujouan 2024), highlighting a heterogeneous evolution across societies.

While regional differences in late fertility have been acknowledged, the geographic process shaping them has yet to be fully understood. Some regions experienced increases in late fertility rates earlier than others (Beaujouan 2020; Riederer and Beaujouan 2024; Šprocha and Fitalová 2022), suggesting that the spread did not occur randomly in space and time. As geographically close regions tend to have more social, economic, and cultural interactions, they can more readily exchange new information and ideas. This interconnectedness can also facilitate the diffusion of new behaviours, making adoption more likely in nearby regions than isolated ones (Morrill et al. 2020; Saint-Julien 2007). Evidence of such spatial dependence exists for various family-related behaviours (e.g. Doignon et al. 2020; Vitali and Billari 2017). However, whether this is relevant for the timing of childbearing, and in particular for late fertility trends over time, has been overlooked.

Understanding the geographic process is crucial because a continued and intensified spread of late fertility could have significant socioeconomic and health implications. As more women have children later in life, they face increased health risks during pregnancy and delivery. In addition, women trying to conceive at older ages encounter a shorter reproductive window and a higher risk of not realizing their fertility intentions (Sauer 2015; Schmidt et al. 2012), as the likelihood of conceiving within a year drops from 75% at age 30 to 66% at 35″ and 44% at 40 (Leridon 2004). Studying the recent evolution of late fertility behaviours can provide key insights into future fertility challenges that regions may face and how geographic patterns are likely to evolve further.

Our study provides an unprecedented examination of the geographic process behind the recent increase in the contribution of late fertility to total fertility in European regions. Across the whole continent, such contribution rose from 16.6% in 2006 to 22.8% in 2018. We hypothesise that a diffusion effect, driven by geographic proximity, is a key factor in shaping this spread. Specifically, we examine how the level of late fertility behaviours in neighbouring regions during period $t - i$ affects the level in a region in the following period t. To test our hypothesis, we analyse data from 193 regions across 18 European countries using a dynamic spatial panel model. By controlling for well-established contextual factors associated with later fertility (Campisi et al. 2023; Riederer and Beaujouan 2024; Šprocha and Fitalová 2022), we aim to isolate the diffusion effect from changes in the socioeconomic environment (e.g. tertiarisation of education). Hereby, our study 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 emphasises spatial dependence.

2 Background

2.1 The Geography of Late Fertility

Births at advanced ages (above 35) are not a new demographic observation. In the early 1950s, women often started a family in their twenties, and late births were mainly of higher birth order (Billari et al. 2007; Prioux 2005). The contemporary trend, however, presents a significant shift in the characteristics of late births since the 1970s. With the emergence of delayed fertility behaviours, many women now wait until their early thirties to start a family. Consequently, late births are increasingly associated with becoming a parent or having a second child (Beaujouan and Sobotka 2019). This shift in the parity of late births also 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 the upward trend in births at advanced reproductive ages is universally observable across European countries, its onset and pace varied significantly across space (Beaujouan 2020). Late births started to increase in most Nordic and Western European countries in the early 1970s, and about two decades later in Southern and Central and Eastern Europe (CEE). Despite this later start of childbearing postponement, the pace of this increase was higher in Southern European countries, as they rapidly moved to the forefront and exhibited the highest shares in late fertility rates since the mid-2010s (Beaujouan 2020). Conversely, despite rising trends in births at advanced ages, most CEE countries still show relatively low levels of late fertility.

Beyond these cross-country differences in trends, one may wonder whether within-country specificities have persisted over the years. 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. 2023; 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 in Slovakia (Šprocha and Fitalová 2022). This is in line with a study of changes in mean age at childbirth over time in a large number of European regions (Riederer and Beaujouan 2024), although the study provides only descriptive evidence of fertility postponement and no direct evidence of fertility trends at older ages.

2.2 Factors Explaining Geographical Differences In Late Fertility

Geographical differences in late fertility have largely been attributed to contextual factors (Beaujouan and Toulemon 2021). Within countries, economic factors such as education, opportunity structures within the economy and the labour market have emerged as relevant determinants of urban-rural differences, as they shape both individuals' opportunity costs and their life goals (Riederer and Beaujouan 2024; Šprocha and Fitalová 2022).

Education, particularly the shift towards tertiary education, emerges as a key factor. Extensive empirical evidence highlights how longer duration in education is associated with postponing childbirth 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. Consistently, studies conducted at the subnational level demonstrate a strong positive association between high educational attainment levels and late childbearing (Campisi et al. 2023; Riederer and Beaujouan 2024; Šprocha and Fitalová 2022). Across Europe, urban areas tend to have a concentration of tertiary-educated individuals compared to rural areas (Eurostat 2023; Riederer and Buber-Ennser 2019).

Urban environments not only facilitate education but also provide economic opportunities. Across European regions, the more competitive ones, as measured by their ability to offer an attractive environment for firms and residents to live and work, tend to have higher GDP and greater achievements[1] by women (Dijkstra et al. 2023). This association may be mirrored in late fertility rates. Regions characterised by thriving economies and significant high-technology sectors also tend to exhibit higher late fertility rates (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: not only do they tend to hold higher education levels, but also occupy middle or higher-level occupations and possess greater socioeconomic resources. One explanation for their late births lies in the conflict between motherhood and (a potential delay in starting) work, as individuals often prioritise 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).

In addition to favourable economic conditions, unfavourable conditions also contribute to increased late childbearing. Young adults are particularly vulnerable, 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 childbearing plans (Alderotti et al. 2021; Matysiak et al. 2021; Neels et al. 2024). Indeed, income 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). 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 labour markets (Matysiak et al. 2021). Related to this, countries and regions severely affected by economic crises and with significant proportions of young adults disconnected from education and the labour market, such as Southern Europe, also exhibit high rates of late fertility (Beaujouan 2020; Skirbekk 2022:200).

Further, prevailing values and norms can contribute to geographic variation in late fertility. These factors are tied to multiple dimensions, such as gender roles (e.g. traditional beliefs may emphasise women's primary responsibility for child-rearing and domestic duties over

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[1] Achievement is quantified by a composite metric, the Female Achievement index, which shows the level of womens' achievement within a NUTS 2 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.’

economic independence and career prioritization), political and spiritual attitudes (e.g. conservative beliefs may favour early childbearing), and social age deadlines (e.g. in societies where early marriage and childbearing are valued, individuals may feel social pressure to have children at a younger age). Empirical evidence reveals a broader general acceptance of late parenthood across European countries (Lazzari et al. 2024), parallel to the recent upward trends in late births. In addition, positive media portrayals of assisted reproductive technologies and mothers in their forties may also alleviate potential concerns about late childbearing and encourage individuals to postpone (Lahad and Madsen 2016; Mills et al. 2015). At the regional level, social transformations regarding family life and values, such as the share of dissolved partnerships and the extent of the vote for conservative parties, have also been shown to be relevant for explaining age-specific fertility rates above the female age of 30 in Nordic European countries (Campisi et al. 2023). These findings may give support to the idea that the spread of new demographic behaviours is partially driven by shifts in values and norms, as posited by the Second Demographic Transition (Lesthaeghe 1995; Van de Kaa 1987). However, similar aspects were found to be less relevant than economic factors in explaining the variation in fertility levels among women over age 35 in European regions in 2018 (Riederer and Beaujouan 2024).

2.3 The Geographical Diffusion of Family-Related Behaviours

While contextual factors may enable or hinder the rise and spread of late fertility in Europe, little attention has been given to its geographic pattern. The literature provides substantial evidence suggesting that the spatial spread of new demographic behaviours may not be random. Rather it can be explained by processes of social influence and learning (Bongaarts and Watkins 1996; Costa 2015; Montgomery and Casterline 1996; Rogers 1983). Social learning refers to how individuals gather information to construct their ‘information set' for making informed decisions. This process can be facilitated through kinship ties, social networks, or mass media. For instance, media portrayals of mothers in their forties can provide information on the costs and rewards of late childbearing and childrearing. Similarly, direct observation of one’s immediate environment informs and influences one’s reproductive decision-making (Balbo and Barban 2014; Bernardi 2003). While social learning equips individuals with the information needed to make informed decisions, social influence stems from interactions with others. Here, individuals' decisions can be affected by the anticipated rewards or sanctions from other group members. For instance, if late motherhood is met with little social approval compared to traditional age deadlines, individuals may opt for earlier childbearing decisions to minimize disapproval within their group and align with societal norms.

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. Individuals are nested within households, administrative regions, countries, and other contexts, all of which may be layers influencing one's decisions to adopt a behaviour (Vitali and Billari 2017). Studies of family-related behaviours have validated the link between space and behaviour adoption, exemplified by the historical transition to low fertility (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). For late fertility, it is possible that a geographic process is also at play to explain the differences in the onset and pace of fertility timing across Europe (Riederer and Beaujouan 2024; Beaujouan 2020).

Within the realm of diffusion geography, scholars have defined two specific patterns of diffusion: contagious and hierarchical (Morrill et al. 2020; Saint-Julien 2007). Hierarchical diffusion involves the spread of a phenomenon along specifically organised channels of influence. For instance, a behaviour may diffuse along the urban hierarchy, from large urban centers to smaller towns. Throughout Europe, urban regions stand out for their widespread late fertility behaviours (Riederer and Beaujouan 2024; Šprocha and Fitalová 2022), which may indicate such a pattern of diffusion.

The second pattern of spread, contagious diffusion, hinges on geographic proximity. In this paradigm, contact probabilities decrease with distance rather than following hierarchies. Inherited from diffusion patterns of infectious diseases, the analogy indicates that the spread occurs along proximity to geographic units. The idea behind this diffusion by geographical proximity is reflected in the work of Waldo Tobler (1970:236), who succinctly captures it as follows: '[…] everything is related to everything else, but near things are more related than distant things.' Evidence of such spatial dependence exists for various family-related behaviours and has been demonstrated with spatial econometric models (e.g. Doignon et al. 2020; Vitali and Billari 2017). Specifically, these studies demonstrate that behaviours in neighbouring areas influence the behaviours in a given area during the same period. While this conceptualization is widely adopted, recent studies have also been able to test a temporal lag in the diffusion process, suggesting that current behaviours in an area can be explained by previous behaviours in proximate areas (Ciccarelli and Elhorst 2018; Costa et al. 2021). As the timing of parenthood appears to be regionally clustered (Riederer and Beaujouan 2024), geographic connectedness, relevant to diffusion by geographical proximity, is very likely to play a role in the evolution of late fertility. At the same time, modern mass media enables the rapid dissemination of ideas across vast and disconnected regions, which may make geographic proximity less relevant. However, despite increasing digitalization, research shows that the connection between space and behaviour continues to play a significant role. For instance, this is evident in contemporary patterns of low fertility (Vitali and Billari 2017; Wu et al. 2022) as well as cohabitation behaviour (Vitali et al. 2015), emphasising that societies are connected in ways that allow demographic behaviour to gradually spread across space.

The existence of one diffusion channel does not rule out the existence of the other. For instance, Doignon et al. (2020) descriptively show that nonmarital cohabitation has diffused across both the contagious and hierarchical dimensions in Belgium, indicating that both channels can contribute to the spread of a phenomenon. Dual diffusion channels may also characterise the spread of late fertility. Previous studies point towards capital regions pioneering the upward trend in late fertility (Riederer and Beaujouan 2024; Šprocha and Fitalová 2022). However, high rates of late births are not exclusive to these areas, but are also found in small commercial or university towns and working-class cities with a mining and manufacturing heritage (Riederer and Beaujouan 2024). In addition, empirical evidence shows that late fertility is not exclusively an urban phenomenon. As shown by Riederer and Beaujouan (2024), there is an additional regional pattern in fertility timing. Beyond the urban-rural divide, the pronounced shift towards later childbirth across Mediterranean regions can be attributed to a later transition to adulthood and increased economic challenges in meeting the requirements for parenthood. These empirical observations challenge the idea that diffusion may be solely hierarchical. To deepen our understanding of the spatiotemporal dynamics of this spread, we focus here on testing the potential existence of a diffusion by geographic proximity dimension.

2.4 Hypothesis

Building on this, we test the following hypothesis: geographic proximity is an important driver of the spread of late fertility, as societies in geographically close regions are more likely to share similar resources and engage in social, economic and cultural interactions. Diffusion by geographic proximity (sometimes referred to as contagion) may represent a novel dimension for explaining how late fertility behaviours spread, reflecting how societies are connected and evolve. We anticipate that this process will persist even when accounting for well-established contextual factors such as changing economies and labour markets. Our hypothesis aligns with recent work that conceptualizes diffusion as a process involving a temporal lag. It suggests that past behaviours explain behaviours today, hence that diffusion is driven by a time lag. The formal expression of our hypothesis is thus as follows:

> *Formal diffusion hypothesis: Late childbearing behaviours in a given region in the period* t *are influenced by the behaviours observed in nearby regions earlier* $t-i$.

3 Econometric Framework

3.1 Data

The primary data source for this study is the Eurostat database, which provides regional statistics on demographics, education, labour markets, and the economy. This database harmonises regional data from national statistical authorities, enabling consistent cross-country comparisons. To fill data gaps, we supplement Eurostat with data from national statistical offices[2]. In addition, we source one variable from the European Spatial Planning Observation Network (ESPON). The regional classification of all employed data 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 (2006–2018) to study the propagation of late fertility behaviours across space. Additionally, the NUTS 2 level aligns with our research objectives, as it represents the basis on which regional policies are implemented, 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 time period t. Our baseline measure is the sum of age-specific fertility rates of women between ages 35 and 49 divided by the total fertility rate (TFR) of a region

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[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.

(Eurostat online data code: demo_r_frate2). Age 35 is commonly used as a threshold to define late fertility in the literature (Sauer 2015; Billari et al. 2007; Prioux 2005; Beaujouan 2020), as female fecundity declines sharply after this age (Leridon 2004). We also assess the sensitivity of our findings using a more restrictive measure by limiting the age range to 40–49 years. For 2018, data on 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 et al. 2009; Yeh et al. 2014).

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

To isolate the spatiotemporal diffusion effect, 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), categorised 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 nonformal) in the 4 weeks preceding the EU-Labour 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 kilometres[3].

Our sample is a balanced panel that comprises 193 regions at NUTS 2 level within 18 European countries, spanning the years 2006 to 2018. This selection aims to provide the longest consistent time series across the largest feasible range of regions. Table 1 presents its summary statistics. All data adhere to the 2016 amendment of the NUTS 2 classification (Commission Regulation (EU) 2016/2066), which categorises 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. 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 Supporting data from national statistical offices, 0.2% of all observation points are

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

[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).

missing. To achieve a balanced panel, which is a prerequisite for our analysis, we predict missing values by selecting the best-fit autoregressive integrated moving average models based on the AIC value.

3.2 Methods

We employ a dynamic spatial Durbin model (DSDM) to analyse the geographic process of the rise and spread of late fertility in Europe across time. This model stands as one of the latest advancements in spatial econometrics and has only recently been implemented in statistical software environments (Bivand et al. 2021; Elhorst 2012; Simonovska 2024). By integrating both spatial and dynamic components, the DSDM offers a sophisticated framework for testing our diffusion hypothesis.

Both theoretical and statistical considerations drive the model selection. First, our study is grounded in the observation that late childbearing behaviours exhibit significant spatial dependence: regions with high contributions of late fertility tend to be surrounded by similar regions and the other way around. This is evidenced by significant and positive Moran's I statistics (a measure of spatial autocorrelation) for both our baseline and more restrictive measures of late fertility across each year of observation and different neighbourhood structures (e.g. ranging from 0.5 to 0.7, see Table A2 in the Appendix). While a simpler spatial autoregressive (SAR)-type 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 of a spatial Durbin model (SDM) 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 SDM-type models 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 matter, as a multi-channel spread may also occur, facilitated by mass media, where networks easily extend beyond geographic boundaries. For instance, a positive media portrayal of assisted reproductive technologies and mothers in their forties may alleviate potential concerns and encourage women to have children later in life (Lahad and Madsen 2016; Mills et al. 2015).

Lastly, previous studies have 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 (SDM) prevalent in all but one of these studies (Ciccarelli and Elhorst 2018), we opted for a dynamic version (DSDM). Instead of attributing the variation in late childbearing at the period t to late fertility in nearby areas within the same period, we consider the previous time period

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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).

$t - i$. This temporal lag aligns with the conceptualization of recent work (Costa et al. 2021; Ciccarelli and Elhorst 2018), acknowledging spatial diffusion as a process shaped by historical behaviours. The inclusion of a temporal lag allows us to clearly differentiate the effects of past diffusion and current clustering (parameters η and δ in the following), which would not be possible in a static specification. Nevertheless, we also present static model estimations alongside our preferred (dynamic) specification to highlight the differences between the two concepts.

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

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

where Y_t is an $N \times 1$ vector representing 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, with N representing the number of regions under study and K the number of variables. The subscript $t - i$ indicates a temporal lag, where i represents the number of lag periods[6]. For our analysis, we limit the lag length to 1 year ($i = 1$), as recent data typically captures the most immediate dynamics and offers stronger predictive power for the near future—a principle that is well grounded in time series forecasting. This restriction not only maintains model parsimony but also aligns with evidence suggesting that individuals' fertility decisions respond to recent events or information, such as labour market uncertainties or economic instability (Matysiak et al. 2021).

W is a $N \times N$ connectivity matrix that introduces a spatial lag, capturing interdependencies between regions. 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 control 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 estimated by the Maximum Likelihood estimator using the *SDPDmod* package in the software environment R (Simonovska 2024).

Neighbourhood connectivity is operationalised through a row-normalised binary contiguity matrix based on the queen criterion, denoted as W^1. In this matrix, adjacency between regions is represented by $w_{t,j}^1 > 0$ for neighbouring regions i and j, and $w_{i,j}^1 = 0$ otherwise. By convention, self-neighbour relations are excluded, ensuring that all diagonal elements are zero, $w_{i,\mathrm{i}}^1 = 0$. In other words, this matrix captures the spatial structure of immediate neighbourhood relationships and defines potential diffusion occurring through late fertility behaviours in regions that share a common border or a vertex with the observed region. This type of connectivity is frequently employed in modelling diffusion processes (Brée and

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[6] In this analysis, we limit the lag period to a single reporting year. This lag does not necessarily represent a 1-year difference in vital events but instead corresponds to a reporting period, which may be shorter or longer than a calendar year.

Doignon 2022; Ciccarelli and Elhorst 2018; Vitali et al. 2015; Vitali and Billari 2017) and is relevant to test our diffusion hypothesis.

In spatial analysis, inference is conditioned on the spatial weight matrix (Anselin 2013; Halleck Vega and Elhorst 2015). There are different ways to conceptualise diffusion by geographic proximity: it can involve very close neighbourhoods (e.g. direct neighbours sharing borders as in our main specification W^1) or far-reaching neighbourhood definitions (e.g. including neighbours of neigh-bours). We expect closer neighbourhood definitions to be more appropriate than very-far-reaching ones, as they capture localized neighbourhood effects.

To further provide a more comprehensive understanding of the response to changes in connectivity, we also test alternative neighbourhood structures. Those include higher-order contiguity (including neighbours of neighbours) and distance-based matrices. We test the sensitivity of potential diffusion by geographic proximity using a total of five alternative conceptualizations of neighbourhoods. Expanding beyond our primary choice of W^1 we also consider a second-order contiguity matrix denoted as W^2. This connectivity is more far-reaching as it includes indirect connections through shared neighbours: i.e., for regions i and j, $w_{i,j}^2 > 0$ if they share at least one common neighbour, otherwise $w_{i,j}^2 = 0$. Next, we explore four different distance-based matrices, all based on the geodesic distance between centroids of regions (Karney 2013). We employ inverse-distance matrixes, denoted as W^{inv}, which adjust 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 analysis, we test for slight ($\varphi = 2$) and quicker ($\varphi = 4$) decay. Both types can be seen as more far-reaching compared to W^1 as they give some weight to all regions in the sample. Lastly, we consider k-nearest neighbours spatial matrices W^{knn} that focus on a predefined number of neighbours, starting with those closest in distance to centroids. Unlike the flexible concept in W^1 and W^2, where the number of neighbours can vary, the number of neighbours that receive a weight in W^{knn} is predetermined. This allows us to test very close definitions, such as with four neighbours W^{knn4}, as well as more far-reaching specifications with eight neighbours W^{knn8}. Both clearly deviate from the average number of neighbours in the contagious specifications, which are 4.8, for W^1 and 14.1 for W^2.

4 Results

4.1 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% and 20%. Only a few regions exhibited higher rates, primarily in Southern Europe and major urban areas. The maps from 2012 to 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%.

Spatial heterogeneity in the prevalence of late fertility behaviours is evident throughout the observation period. As depicted in Figure 1, there are clear within-country patterns. For instance, in 2006, the Spanish region of País Vasco, which is located at the Western end of the Pyrenees, recorded the highest contribution at 30.3% across all European regions. Not all of the Spanish regions mirrored such high levels. Andalucía, located at the opposite end, had the lowest contribution within the country, at 21.2%. 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.

The distribution also suggests spatial clustering, with regions sharing similar levels often being close to each other. This pattern is exemplary for País Vasco where adjacent areas exhibit increasingly similar high shares across all maps. Likewise, once the Spanish capital region Comunidad de Madrid gains momentum, nearby regions also reach higher levels (see 2012 and 2018). In most cases, such a tendency of spatial clustering does not halt at national boundaries. In that regard, the case of Spain stands as one of the few exceptions.[7] However, for most other borders, such a sharp discontinuity is not observed. 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 (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 behaviours 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 timespan. Light dots on the graph represent individual regions, darker dots indicate the mean value of all regions within each country and stars mark each country's capital region. The horizontal line corresponds to the average increase across all overserved European regions. Every single region recorded an increase between 2006 and 2018. This rise has been greater in capital regions (despite already exhibiting higher rates) in most countries (except for Italy, Poland, Portugal and Spain), widening the gap with noncapital regions. Thus, capital regions have not slowed down but rather set themselves further apart from their country counterparts. As a result, they often occupy a

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[7] We notice that the border with France seems to somewhat slow down the spread of late fertility behaviour. It may be that factors such as the countries' specific socioeconomic features (generally weaker economic position of Spain compared to France) explain why the spread seems to slow down at borders. We also observe a discontinuity between Spain and Portugal, evident in 2006 but fades by 2018. Although Portugal has historically shared similar economic, social, and political trajectories with Spain (Dominguez Folgueras and Castro-Martín 2008), one possible explanation is that women in Portugal tend to express more traditional gender role attitudes (Dominguez Folgueras and Castro-Martín 2008), and show lower acceptance of later motherhood (Lazzari et al. 2024), both of which may result in greater social pressure to form a family earlier.

forerunning position—a factor that could potentially drive diffusion by geographic proximity patterns.

The differences in increases may be explained by shifts in socioeconomic features. For instance, in Spain, 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 partly account for the heightened rates that have even surpassed those of Madrid. Conversely, elevated late fertility contributions in the South of Spain may rather have developed in response to adverse economic conditions. Overall, regional trends in socioeconomic indicators align with increases in late fertility behaviour. Figure 3 depicts them, differentiating between capital and noncapital regions. Despite notable differences in their levels, there are similarities in terms of general trends across both types of regions. Particularly noteworthy is the almost parallel trend observed between late fertility and the proportion of women with tertiary education since 2006 both in capital and other regions. Despite these indicators following nearly identical paths, their correlation coefficient remains relatively low at 0.16 in the case of noncapital 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).

We leverage several observations from the descriptive analysis, which are also supported (albeit to a lesser degree) when setting a higher 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. Overall, the descriptives point towards the existence of diffusion by geographic proximity. The following section tests whether the observed increase follows a diffusion pattern from forerunning regions to others, facilitated by geographic proximity.

4.2 Estimation Results

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 *diffusion 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 diffusion by geographic proximity (Column 2), indicated by WY_{t-i}, shows a considerably lower parameter compared to a static one (0.138 vs. 0.784). Holding other factors constant, late childbearing behaviours in a specific region and period appear to be significantly influenced by the behaviours observed earlier in neighbouring regions. This association is even stronger when late fertility is defined from age 40 rather than from age 35 (Column 4). Besides the diffusion process, the positive parameter of WY_t suggests that regions with similar levels of late fertility continue to cluster together. Furthermore, a strong positive association between past levels (Y_{t-i}) and current ones reinforces the persistence of late fertility patterns over time.

Table 3 presents how the choice of neighbourhood connectivity structure affects the estimation results. We find evidence that the strength of the diffusion by geographic proximity effect (WY_{t-i}) decreases as the neighbourhood range increases. This pattern is expected, as expanding the range alters the scale of analysis: smaller ranges capture more localized regional effects, while larger ranges reflect broader macroregional or national influences.

Compared to our main choice of a binary contiguity weights matrix W^1, the use of a secondary contiguity weights matrix (Column 1), where neighbours' neighbours are additionally included, shows that the diffusion effect weakens with more far-reaching connectivity. This reflects the changing influence of an average of 14.1 neighbours in W^2 versus 4.8 neighbours in W^1. Distance-based matrices further support this finding. When testing an even more generous specification where connectivity is not restricted to sharing common borders but generally decreases across the whole geography 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-i}. Only the very restricted distance-based version ($W^{inv\varphi4}$ in Column 3), which emphasises closer regions, shows similar patterns to the binary contiguity connectivity. We find a similar pattern for k-nearest neighbours specifications (Columns 4 and 5) and corroborate our previous observation that regions closer in proximity tend to exhibit a stronger influence on each other compared to regions that are farther apart. Finally, results for the 40-year age threshold further confirm that smaller neighbourhood ranges capture more regional neighbourhood effects of late fertility spread. These results are available in Table A4 in the Appendix.

5 Discussion and Conclusions

This paper has examined the geographic pattern 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 spatial diffusion processes has remained overlooked. As societies become increasingly interconnected in social, economic and cultural terms, such geographic proximity may facilitate the adoption of demographic behaviours from forerunning regions to nearby others. Our analysis addressed this gap and employed a dynamic spatial Durbin model to assess whether a spatial diffusion process has shaped the evolution of the contribution of births over age 35 to total fertility levels between 2006 and 2018.

Our results present robust evidence of a pattern of diffusion by proximity in the spread of late fertility across Europe. This means that late childbearing behaviours in a given region are influenced by the behaviours observed in neighbouring regions earlier. We find this geographic pattern to persist even after accounting for various socioeconomic factors such as education levels, economic conditions, labour market situations, and urbanization levels. Consequently, late fertility behaviours in a region are not just tied to its context but tend to evolve across space as societies are connected and develop. Thus, the transmission of the new behaviours also occurs from forerunning regions to nearby others. In our sample, regions with capitals and major cities exhibit the highest contributions in almost all of the 18 observed countries throughout the entire observation period. Accordingly, they are expected to act as forerunners to a large extent—suggesting diffusion by geographic proximity to be accompanied by a strong (but not sole) influence of urban areas in driving the considerable rise in late fertility rates across Europe.

Our study further underscores the significance of accurately conceptualizing diffusion processes. We find that common static conceptualizations (e.g. Vitali et al. 2015) may over-estimate the degree of geographic diffusion. The development and computational implementation of the dynamic spatial Durbin model is relatively recent. As such, we emphasize its utility while also acknowledging that previous studies, constrained by methodological limitations, had to rely on static conceptualizations as a proxy for spatial diffusion effects. Another aspect involves the selection of the connectivity structure. Nearly all studies examining diffusion effects impose a singular choice of spatial structure: binary contiguity based on the queen criterion (e.g. Brée and Doignon 2022). However, different connectivity structures can yield varying results due to differences in the scale at which neighbourhood effects are measured. In the case of late fertility, we find that among a large set of structures, all those prioritizing a smaller regional range consistently show a spatial diffusion effect, albeit with differing parameter sizes. Despite these differences, all confirm that geographical proximity remains a key factor in capturing late fertility trends, even in the digital age, where mass media could potentially amplify the influence of distant connections. Our results, therefore, support the idea that near things are more related than distant ones (Tobler 1970). Future studies should be cautious when drawing conclusions based on a single connectivity structure or static concepts.

Our 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 behaviours 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 behaviours spread across space.

Additionally, comparing the geographic patterns identified in our study with those reported for other aspects of family change—such as fertility quantum, cohabitation, or nuptiality—would be valuable. However, such comparisons remain challenging due to inconsistencies in time periods, levels of aggregation, and regional coverage across existing studies. Future research adopting a consistent methodological framework across various family behaviours could provide deeper insights into the persistence and variation of geographic diffusion patterns. 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 process of diffusion by geographic proximity. There appears to be a potential amplification exerted by capital regions, corroborating previous indications that late fertility is notably prevalent in urban areas (Riederer and Beaujouan 2024) which also undergo a more pronounced increase (Šprocha and Fitalová 2022).

Our study is not without limitations. First, our findings may be sensitive to the modifiable areal unit problem (Niedomysl et al. 2017), where grouping data into various scales or boundaries can affect analytical outcomes. According to the European Spatial Planning Observation Network (Riosmena and Balk 2024), it is less the case for the level of aggregation we used (NUTS 2) compared to the more granular NUTS 3, due to 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. Riederer and Beaujouan (2024) show that there are no significant disparities in late fertility rates between the two levels of aggregation, mitigating this issue.

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 to and quality of childcare services and housing, 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 child-care services on the transition to parenthood using Belgian regional data. This omission may introduce residual confounding, which we attempt to mitigate by including regional fixed effects.

Third, the fertility indicator we use encompasses all birth orders. 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 realised outcomes but does not indicate whether births are increasingly intended at advanced ages. A rise in fertility intentions over age 35 has been documented in Austria (Beaujouan 2022) and may also apply to other areas. This prompts questions about whether our measure captures inequalities in knowledge and access to infertility treatment (e.g. Goisis et al. 2024), as late fertility trends have been accompanied by a rise in assisted reproduction activity (Smeenk et al. 2023).

Despite these limitations, our study emphasises that late fertility has become increasingly widespread at the subnational level, not least due to the combined influence of socioeconomic transformations and diffusion processes. As this trend shows no signs of plateauing, even in regions where high levels have already been reached, diffusion processes may lead to even higher prevalence in the coming years, particularly in regions close to forerunners where the trend is already established.

The implications of a continued spread of late fertility behaviours are significant. Economic conditions at the regional level play a decisive role in the occurrence of late births. Accordingly, tackling issues like job insecurity or insufficient income regionally may help create a more favourable environment for individuals to realise their reproductive plans. Additionally, as more women have children later in life, more are likely to face biological constraints or infertility issues. As a result, and despite the limited infertility treatment success rates at older ages (e.g. Malizia et al. 2009), the demand for assisted reproductive technology is expected to increase too. Also on that matter, the regional context is likely to remain crucial, as proximity to a fertility clinic affects accessibility (Jones et al. 2023; Lazzari et al. 2022; Mackay et al. 2023) and reimbursement policies for infertility treatments vary between regions in some countries (e.g. in Italy, Spain or Poland).

Overall, the rise in late fertility is a common challenge for European countries, as it can contribute to a higher prevalence of childlessness and lower overall fertility (Beaujouan et al. 2023). Our study highlights the geographical dimension of the rise in late fertility, showing that varying levels can be systematically explained by regional diffusion patterns over time. It becomes clear how closely interconnected the regions across Europe are and will likely remain. As late fertility continues to spread, fostering open dialogue across geographies is crucial. Developing comprehensive strategies that support women in their reproductive decisions locally, while leveraging synergies across regions—through sharing knowledge, resources, and best practices—will be essential to effectively address these challenges jointly.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Data Availability Statement

The data that support the findings of this study are openly available in Eurostat database at https://ec.europa.eu/eurostat/web/main/data/database.

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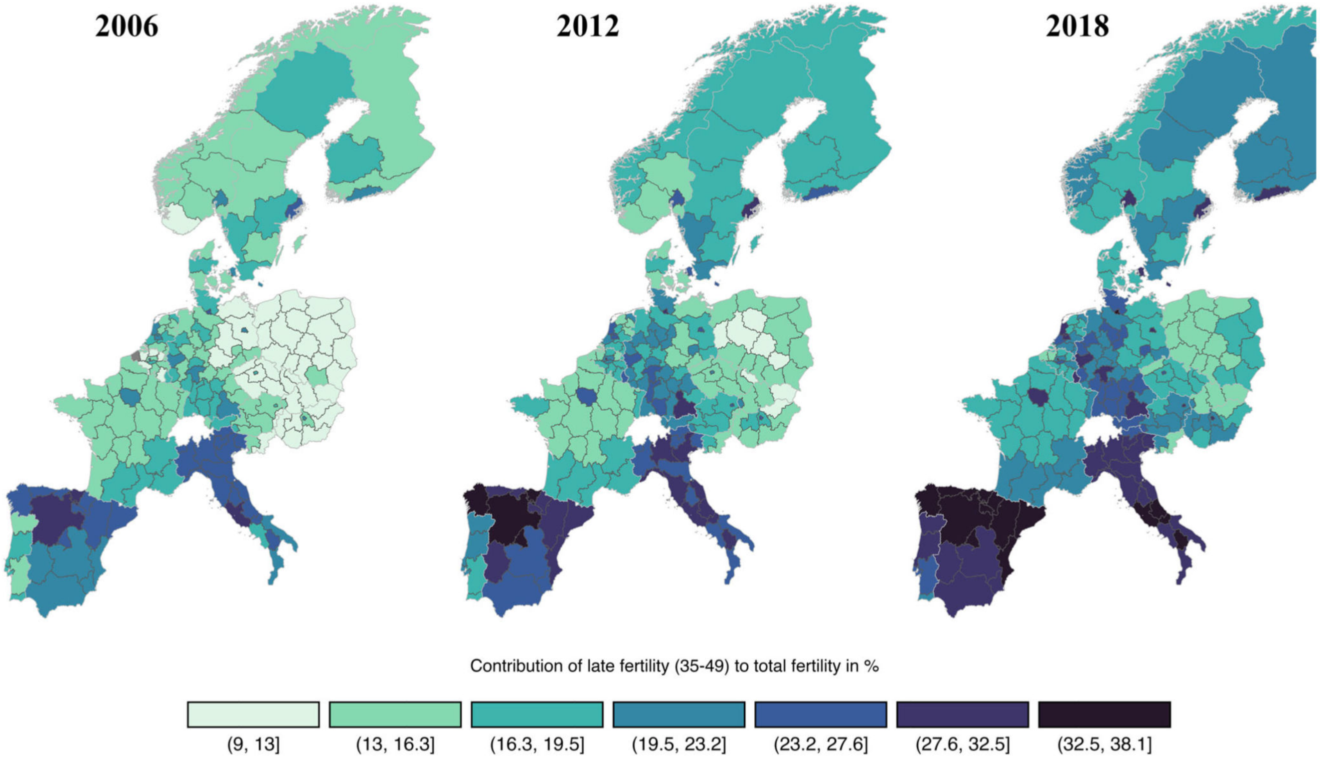

Figure 1. Spatial trend of the contribution of late fertility rates (35–49) to total fertility at NUTS 2 level.

Note: Summary statistics for 2006: Mean 16.6, SD 4.9, Min 9.0, Max 30.3. 2012: Mean 20.1, SD 5.4, Min 12.3, Max 34.4. 2018: Mean 22.8, SD 6.0, Min 13.1, Max 38.1. Eurostat (online data code: demo_r_frate2) and national statistical offices.

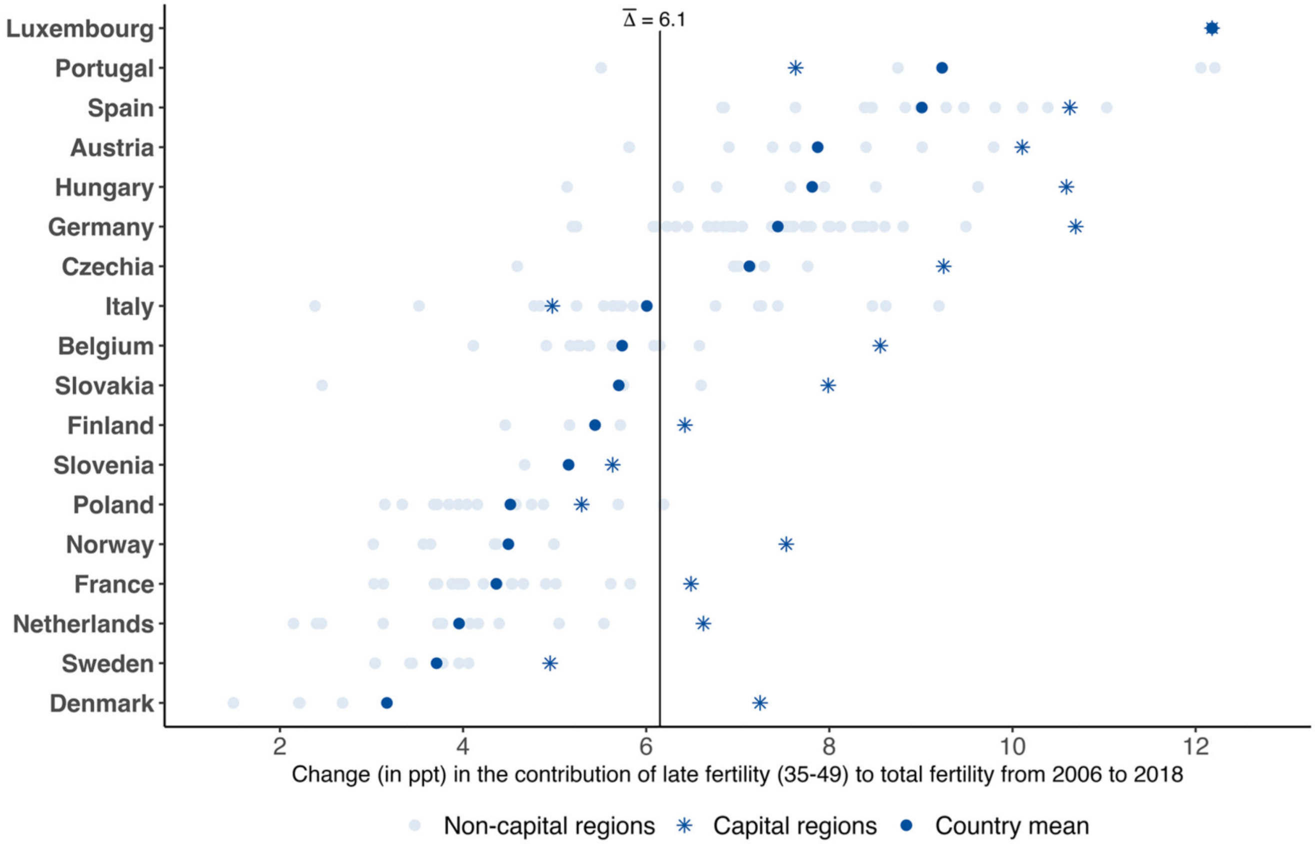

Figure 2. Temporal trend of the contribution of late fertility rates (35-49) to total fertility at NUTS 2 level.

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

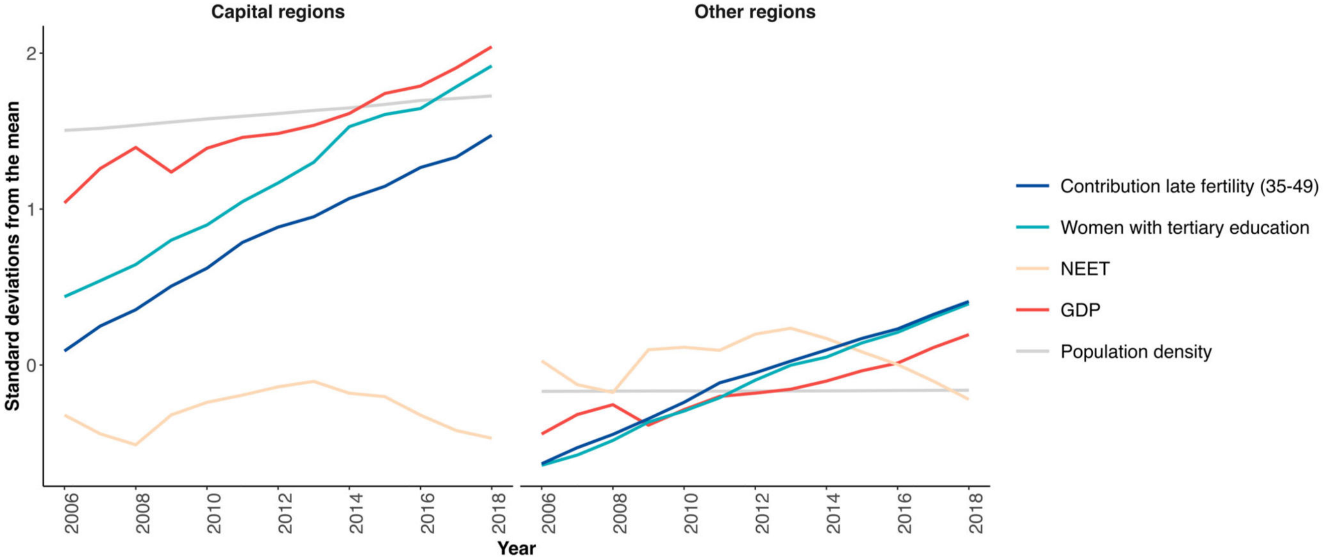

Figure 3. Evolution of key socioeconomic indicators between 2006 and 2018 (standard deviations from the mean).

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

Table 1 Summary statistics.

	2018				
	Mean	**SD**	***Min***	***Max***	**$\Delta_{(2006,2018)}$**
% 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				

Note: 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.

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			
	Baseline measure 35–49		**More restrictive measure 40–49**	
	(1)	**(2)**	**(3)**	**(4)**
WY_t	0.784^{***}	0.343^{***}	0.747^{***}	0.356^{***}
Y_{t-i}		0.454^{***}		0.373^{***}
WY_{t-i}		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^{***}
W Women with tertiary education	0.061^{***}	0.010	0.082^{***}	−0.023
W NEET	0.044^{***}	0.005	0.064^{***}	0.020
W GDP	-0.113^{***}	-0.119^{**}	-0.163^{***}	-0.117^{**}
W Population density	-1.072^{***}	-0.360	-1.297^{***}	-0.779^{*}
Observations	2509	2316	2509	2316
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

Note: All variables are standardised. All models employ a row-normalised binary contiguity W^1 matrix. 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.

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-i}	0.487***	0.474***	0.469***	0.444***	0.468***
WY_{t-i}	0.007	0.043	0.154***	0.114***	0.026
Observations	2316	2316	2316	2316	2316
W	W^2	$W^{inv\varphi2}$	$W^{inv\varphi4}$	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

Note: All variables are standardised. Controls include women with tertiary education, NEET, GDP, and population density. Models employ different connectivity matrices: row-normalised secondary contiguity matrix $\boldsymbol{W^2}$, inverse-distance matrices with benchmark value $\boldsymbol{\varphi}$ equal to 2 $\boldsymbol{W^{inv\varphi2}}$ or 4 $\boldsymbol{W^{inv\varphi4}}$, and k-nearest neighbour matrices considering four $\boldsymbol{W^{knn4}}$ or eight neighbours $\boldsymbol{W^{knn8}}$. 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.