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RESEARCH ARTICLE OPEN ACCESS

Can Spatial Diffusion Process Explain Family Changes? A Spatio-Temporal Analysis of Nonmarital Births Over 50 Years in Belgium (1968–2017)

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ABSTRACT

Over the decades, many European countries have experienced significant changes in the family, characterised by declining marriage rates, increasing cohabitation, delayed childbearing and persistently low fertility. The *Second Demographic Transition* (SDT) has been a key framework for understanding these shifts, with alternative theories focusing on economic, cultural, and gender-related factors. Despite extensive research, the geographical dimension of these changes remains underexplored, in particular a detailed spatio-temporal analysis of the determinants of their spatial dynamics from their onset. This study fills this gap by examining the spatial dynamics of nonmarital births in Belgium over the last 50 years at the municipal level and by tracing the evolution of key explanatory variables. Using spatial modelling, we find a significant spatial diffusion effect, i.e. that nonmarital birth rates in a municipality are influenced by rates in neighbouring municipalities from previous periods. This finding highlights the importance of geographical proximity as a key determinant of family change, alongside socioeconomic factors. In addition, the study identifies the factors driving these spatial dynamics, quantifies their relative impact, and systematically ranks them across time. It suggests that different theoretical frameworks are relevant to explain the different stages of the diffusion process. Our findings emphasize the need to integrate multiple theoretical perspectives to achieve a comprehensive understanding of the family changes.

1 | Introduction

Since the late 1960s, several European countries have experienced significant changes in the realm of family. These changes include declining nuptiality, delayed marriage and childbearing, increasing prevalence of divorce, unmarried cohabitation and nmarital births. There is a theoretical debate about which explanatory dimension is responsible for the emergence and evolution of these family changes (Zaidi and Morgan 2017). However, in this extensive literature, the geographical dimension remains one of the least studied. Yet, the evolution of

family changes has shown significant regional and temporal variation influenced by cultural, economic, and political changes (Shorter et al. 1971; Kiernan 2001; Klüsener 2015; Esteve and Lesthaeghe 2016). It is important to see how family changes are spread geographically, as this can provide crucial elements in the theoretical debate on family changes. Several studies have taken a spatiotemporal approach to investigate how changes in family behaviours are spread across space and time (Vitali et al. 2015; Bleha and ĀurĀek 2019; Caltabiano et al. 2019; Doignon et al. 2020; Doignon 2021). They have shown that these changes are not random, but follow a

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structured spatial diffusion process, influenced by geographical proximity and urban hierarchy, with urban areas often being the leading regions. However, with some exceptions, this type of study has remained mainly descriptive. We still have a lot to learn about explaining the spatial dynamics of family changes.

Therefore, in this article we aim to (1) investigate whether the spatial dynamics of family changes can be explained by socio-economic factors alone, or whether there is also a spatial diffusion effect, and (2) to analyse which explanatory dimension(s) is (are) most relevant to explain these spatial dynamics over time. To investigate this, we choose to examine nonmarital births in Belgium over a period of more than 50 years and at the municipal level. The descriptive results clearly show a spatial diffusion process of nonmarital births in this country. Spatial modelling is therefore used to account for this spatial dependence, with a two-stage analytical strategy.

The paper is original for two reasons. First, most existing studies with a spatio-temporal approach to family change do not go back far enough in time to include the early stages of diffusion. Our study period starts at the end of the 1960s, covering the entire spatial spread of this phenomenon. It is therefore highly original to take a spatio-temporal approach in explaining a family change with both this historical depth and a local geographical level. The second original feature is the detailed analysis of the evolution of the explanatory power of each factor over time, thus demonstrating the need to mobilise several theories to understand the evolution of family change over time.

2 | Background

2.1 | The Theories of Family Changes

Family behaviour in Europe has changed significantly since the 1960s. Marriage rates have fallen sharply, divorce rates have risen, as have the nonmarital births and the age at which people have children or get married. These are major changes in the contemporary history of European societies, which we call ‘family changes’. A number of theoretical frameworks have been proposed to explain these family changes. Contrary to common practice, we have chosen to present the main theories in chronological order (Figure 1). We believe that the explanations offered by each theory are partly related to the

historical context in which they are set. Our presentation is not intended to be exhaustive.

The first major theory on family changes is Gary Becker’s *New Home Economics* (1981). This economic theory was developed following the post-war increase in women’s participation in the labour market in many Western countries, particularly the United States. According to this theory, the interest and the attractiveness of marriage is mainly explained by the division of labour and the complementary skills of the spouses. Accordingly, marriage becomes less attractive for women as they enter the labour market, become financially independent and are no longer confined to the domestic sphere. In this context, divorce becomes an advantageous option. The key factor is the participation of women in the labour market. However, this theory focuses mainly on marriage and divorce and does not take into account all the family changes that took place at the time.

The theory of the *Second Demographic Transition* emerged subsequently (Van de Kaa and Lesthaeghe 1986). Its founders based their explanations in part on the observation that family changes were occurring in a region (North-West Europe) during a period of major ideological and cultural shifts (1960-1970). These shifts included, for example, a marked decline in religious practice and an increase in secularisation, as well as more women entering higher education and the labour market. The student protests of 1968 also indicated a questioning of authority. The SDT draws inspiration from Inglehart’s post-modernism (1977). It conceptualises the idea that the economic prosperity and material security of developed societies lead to a reorientation of people’s values, with an emphasis on individualism and personal fulfilment. This process would then affect many areas of social life, especially the family (Lesthaeghe 2014). The key factors are secularisation and education, especially for women. The SDT is the first theoretical framework to propose an explanation for family changes, which are seen as a global change responsible for the below-replacement fertility observed in many European countries since the 1970s. One of the main predictions of the SDT is that the fertility rates will remain below the replacement level. Subsequent theories have very often positioned themselves in relation to the SDT and its main predictions regarding the fertility rates, to offer their own explanations. Despite the fact that the SDT framework has been subject to criticism (Zaidi and Morgan 2017), it has an important place in population sciences for explaining family changes in Europe.

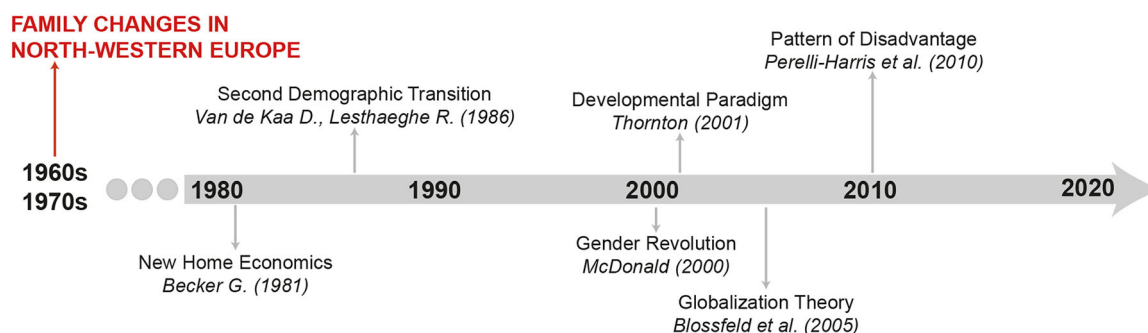


FIGURE 1 | A chronological view of major theories of family changes (non-exhaustive).

In particular, the SDT has been criticised for lacking a gender perspective (Goldscheider et al. 2015). Considering this perspective, the theory of *Gender Revolution* places gender relations at the centre of the explanation (McDonald 2000). It is based on the increase in fertility observed in the Scandinavian countries in the 1990s, while in the vast majority of European countries, fertility rates fell or remained very low. These countries were distinguished from the others by their more balanced gender relations, a feature on which the *Gender Revolution* bases its theoretical explanation of family changes. It focuses on changes in gender roles. As a result of their entry into the labour market, women have gained a degree of financial independence and taken on new responsibilities, particularly providing economic support within the family, which was not the case in the traditional male breadwinner model. This leads to confusion about what men and women expect from each other within the couple when domestic activities are not shared equally, which reduces the willingness of couples to make commitments (marriage, parenthood, etc.). The key factor in this theory is gender equality, both in the public sphere (labour market participation) and in the private sphere (division of labour).

Two theories emerged later, after the acceleration of globalisation in the 1980s. They are possibly rooted in the emergence of global mass media, the increase in economic exchange and trade, etc. One of these theories is based on *globalisation* (Blossfeld et al. 2005) and hypothesises that the uncertainty of the labour market, and of the socioeconomic changes, resulting from globalisation, leads young adults to postpone (or forgo) binding long-term commitments such as marriage and parenthood. Like SDT, the *Developmental Paradigm* theory is founded on the evolution of individual norms and values (Thornton 2001). While SDT was based on the experience of north-western Europe, the initial aim of the *Developmental Paradigm* was to explain family changes worldwide, particularly in the Global South. It is thought that these changes are due to the spread of Western family values over the last few centuries, which have had a major influence on the family systems in other regions, without leading to a convergence towards a global family model.

The latest relevant theory is the *Pattern of Disadvantage* (Perelli-Harris et al. 2010), which is based on the experience of Eastern European countries, where family changes were triggered immediately by the collapse of the USSR and the subsequent economic downturn. It is deteriorating socio-economic conditions that cause these family changes. Unlike SDT, this theory suggests a negative educational and economic gradient, whereby family changes primarily affect socially disadvantaged groups with low levels of education and limited economic resources. Consequently, marriage would remain mainly associated with advantaged and educated groups.

Each of the theories presented above places certain types of factors at the centre of its explanation: cultural change, secularisation and women's education for the SDT and the *Developmental Paradigm*, women's participation in the labour market and gender roles for the *New Home Economics* and the *Gender Revolution*, economic insecurity and unemployment for the *Globalisation* theory and the *Pattern of Disadvantage*. These

differences stem not only from the economic, cultural or gender-related inspiration of the authors, but also from the period in which these theories were conceived.

This theoretical development has generated a large empirical literature and debates that seek to identify which theory is most relevant to explaining family change. This is difficult, however, because the relevant theory for explaining family changes varies across time and space. We suggest that not one but all theories could be relevant, but that their explanatory potential varies across time and space.

2.2 | The Spatio-Temporal Approach to a Comprehensive Understanding of Family Changes

The spatio-temporal approach, i.e. looking at the combined spatial and temporal dimensions, is one way of gaining a comprehensive understanding of family changes. For example, by analysing their spatial dynamics, i.e. where family changes started and how they spread across space, we can better identify the potential factors that trigger and explain how these changes evolved. A spatio-temporal approach can contribute to the theoretical debate on family changes, but research using this approach is still rare (Lesthaeghe et al. 2016).

Family changes in Europe, especially in the past 50 years, show a nonrandom spatial distribution shaped by spatial dynamics and differences in the population compositional characteristics and prevailing contextual conditions (Shorter et al. 1971; Klüsener et al. 2013). Studies have shown that family changes follow a process of spatial diffusion through the two classical mechanisms of geographical proximity and hierarchical diffusion. For example, Doignon (2021) used descriptive maps to show spatial diffusion of the increase in nonmarital births at the 'pseudo-canton' level in France since 1968. Similar patterns are observed in Norway for nonmarital births (Vitali et al. 2015), in post-socialist regions such as Slovakia and the Czech Republic for some family changes (Bleha and Ďurček 2019), or in Belgium for divorce and cohabitation (Doignon et al. 2020, 2022). These studies are mainly based on maps, which effectively show the spatial diffusion of these family behaviours, illustrating how they have gradually diffused from specific areas to wider regions. In explaining the diffusion of nonmarital childbearing in Norwegian municipalities between 1988 and 2011; Vitali et al. (2015) have found evidence of a spatial diffusion effect, measured by a spatial regression after controlling for the other explanatory variables. They have also shown that the explanation for the spatial dynamics can be divided into two stages over time: the first stage explained by economic difficulties, and the second by women's education.

The increase in nonmarital births has occurred at different times and at different rates, with distinct regional patterns both between and within countries. Klüsener et al. (2013) found that nonmarital fertility spread across space in Europe after 1960, while remaining constrained by regional and state borders and closely linked to national borders. The development of modern states has shaped population structures and behaviours through the establishment of standardised institutions such as education, legal systems and a specific history of their secularisation.

State policies and welfare systems have played a central role in cultural and demographic convergence within states, affecting nonmarital births (Klüsener et al. 2013; Klüsener 2015). Indeed, studies have identified borders as an obstacle to the spatial diffusion of family changes (Bleha and Ďurček 2019).

2.3 | Research Gaps and Positioning of the Article

Although valuable insights into the spatial dynamics of family changes have been provided by existing studies, a comprehensive understanding has not yet been achieved due to several gaps in this body of research.

First, studies using this approach are largely descriptive, using maps to highlight the spatial diffusion of family changes. In fact, with a few exceptions (Vitali et al. 2015; Caltabiano et al. 2019; Setz et al. 2025), they do not use models to measure the impact of the socioeconomic factors underlying these statistical spatial dynamics, thus limiting their contribution to the theoretical debate on family changes. In addition, they do not examine the extent to which these spatial dynamics are solely due to other socioeconomic factors, or whether they are also due to diffusion mechanisms. Second, spatio-temporal studies with an explanatory approach often have methodological limitations, such as the use of too aggregated geographical units or too short study period. More importantly, the time period often does not cover the full sequence and generally does not include the onset and initial stages of the diffusion, i.e. when the changes in the family became apparent. This makes it difficult to analyse spatial dynamics accurately and to gain a full understanding of family changes. Third, a major gap is the lack of research that analyses in detail which factor(s) drive the spatial diffusion since the onset of family changes and whether these key factors change over time. To the best of our knowledge, we could not find any study that explains in detail the spatial diffusion pattern of family changes and articulates the determining factors over time. These gaps indicate the need for more explanatory research that integrates a spatio-temporal approach, considers the full sequence of the spatial diffusion, and includes a detailed analysis of the determinants of this process over time, to contribute to the theoretical debate on family changes.

To fill this gap, this article examines the spatial dynamics of nonmarital births over a 50-year period. We chose nonmarital births because they are considered to be one of the most important family changes (Perelli-Harris et al. 2012). They have been increasing steadily across Europe since the late 1960s. By 2018, 42% of the births in Europe were outside marriage. This contrasts sharply with earlier norms that positioned marriage as a prerequisite for family formation and childbearing. This article provides a detailed analysis of the spatial diffusion process from its inception, an aspect rarely explored in the existing literature. In addition, the study identifies the key factors driving this spatial diffusion, quantifies their relative impact, and systematically ranks them across different time periods.

Belgium, our study area, is one of the countries in North-Western Europe where the increase in nonmarital birth began after the 1980s. Until 1987, the prevalence of nonmarital birth

in Belgium was less than 10%, which reached 50% in 2017. It is also one of the first countries where spatial pattern of certain family changes have been studied (Lesthaeghe and Neels 2002; Doignon et al. 2020, 2022). However, there is very little evidence to describe and explain the spatial diffusion of nonmarital births in Belgium. This country has a long tradition of producing statistics at municipal level, which allows us to study the spatial diffusion in detail (high spatial and temporal accuracy) since 1968, i.e. the early stages of the increase in nonmarital births. Moreover, the Belgian data meet all the methodological requirements for a detailed analysis of the spatial dynamics of family changes in a way that has never been done before.

2.4 | Research Questions and Hypothesis

For our article, we have identified the following research questions (RQ) and hypotheses (H).

RQ1. *Is there a spatial diffusion of nonmarital births in Belgium since 1968? If so, is this dynamic solely explained by socioeconomic factors, or is there specific spatial diffusion effect?*

H1. *There is a spatial diffusion effect of nonmarital births in Belgium. This effect persists even after controlling for other explanatory variables.*

RQ2. *Which factors explain the most of the spatial dynamics of nonmarital births in Belgium?*

H2. *No single factor explains the increase in nonmarital births in Belgium.*

The existing theories are based on the deep-rooted factors of human societies: religion, values, unemployment, economic conditions, women's participation in the labour market, women's education, women's conditions, gender relations, etc. The family changes over the past few decades are thus the result of complex, structural and societal transformation. They are too complex to be reduced to a single explanatory dimension or theory.

H3. *The most important factors change over time.*

A factor that explains nonmarital births in one period does not necessarily apply to a another. It makes more sense to consider these different factors as complementary than contradictory. Each factor has the potential to contribute to an overall understanding. For instance, secularisation could be a significant factor in the first 15 years, while unemployment could become the most important factor in the subsequent 30 years.

3 | Data and Methods

This part is divided into three sections. The first deals with data collection, as the construction of a database is a major and time-consuming challenge in research with spatio-temporal approach (Mathian and Sanders 2014). The second section presents exploratory descriptive analyses (mapping and spatial

statistics), which then allow us to select the most appropriate methods for modelling the phenomenon (last section).

3.1 | Data Collection

Belgium is known for its long tradition of statistical recording and the quality of the data produced since the 19th century. However, there is no database at the municipal level going back to the 1960s to perform spatio-temporal analyses and answer our research questions. We therefore had to build the database ourselves by collecting and collating existing data from a variety of sources for several variables of interest (see Table 1). This task was complicated by a number of factors. Firstly, the data was scattered. We had to contact numerous data providers to reconstruct the municipal time series. Second, the data were disseminated in very different formats, depending on the provider and the period. Tabular and electronic data are often available from the 1990s onwards, but rarely before. Fortunately, the Belgian statistical system has been publishing a lot of data at the municipal level for a long time. In some cases, we were fortunate enough to obtain the digitised statistical publications of the time. In other cases, we went directly to the archives to photograph the documents. In both cases, the data was then entered manually, which is a very time-consuming process. For example, to reconstruct the same variable over 50 years, it was sometimes necessary to use data both in the archives and in electronic format, from two different providers.

We therefore collected local data in electronic form for the period 1968–2017. We then had to harmonise these data with the administrative areas. There have been many changes in municipalities since 1968, in particular the major merging in 1976, which reduced the number of municipalities from 2,359 to 596. A further change in 1983 decreased the number of municipalities to 589 and then remained stable until 2017. The number of municipalities has therefore changed considerably

since 1968. Depending on the period considered, the data were compiled for very different numbers of municipalities: more than 2 400 in the 1960s and less than 600 from 1976 onwards. We have therefore converted the data so that there are only 589 municipalities for all the data between 1968 and 2017. To do this, we used a matching table that assigns each municipality that has existed since 1968 to one of the 589 municipalities in 2017. This table did not exist at the time of our study and we had to create it from existing documents and by manually reconstructing the changes in certain municipalities.

Finally, depending on the source, the data were not collected with the same regularity. Depending on the variable, data were collected annually (unemployment, population register, civil status), every ten years (population census) or without a regular cycle (parliamentary elections). To limit the statistical noise due to the effect of small numbers inherent in local geographical units, we have chosen to create 5-year periods (1968-1972; 1973-1977... 2013-2017). The aim of harmonising the data over time was to obtain a value for each variable and each 5-year period. To achieve this, we used linear interpolation for ten-year data and aggregation over 5 years for annual data or data without a regular cycle.

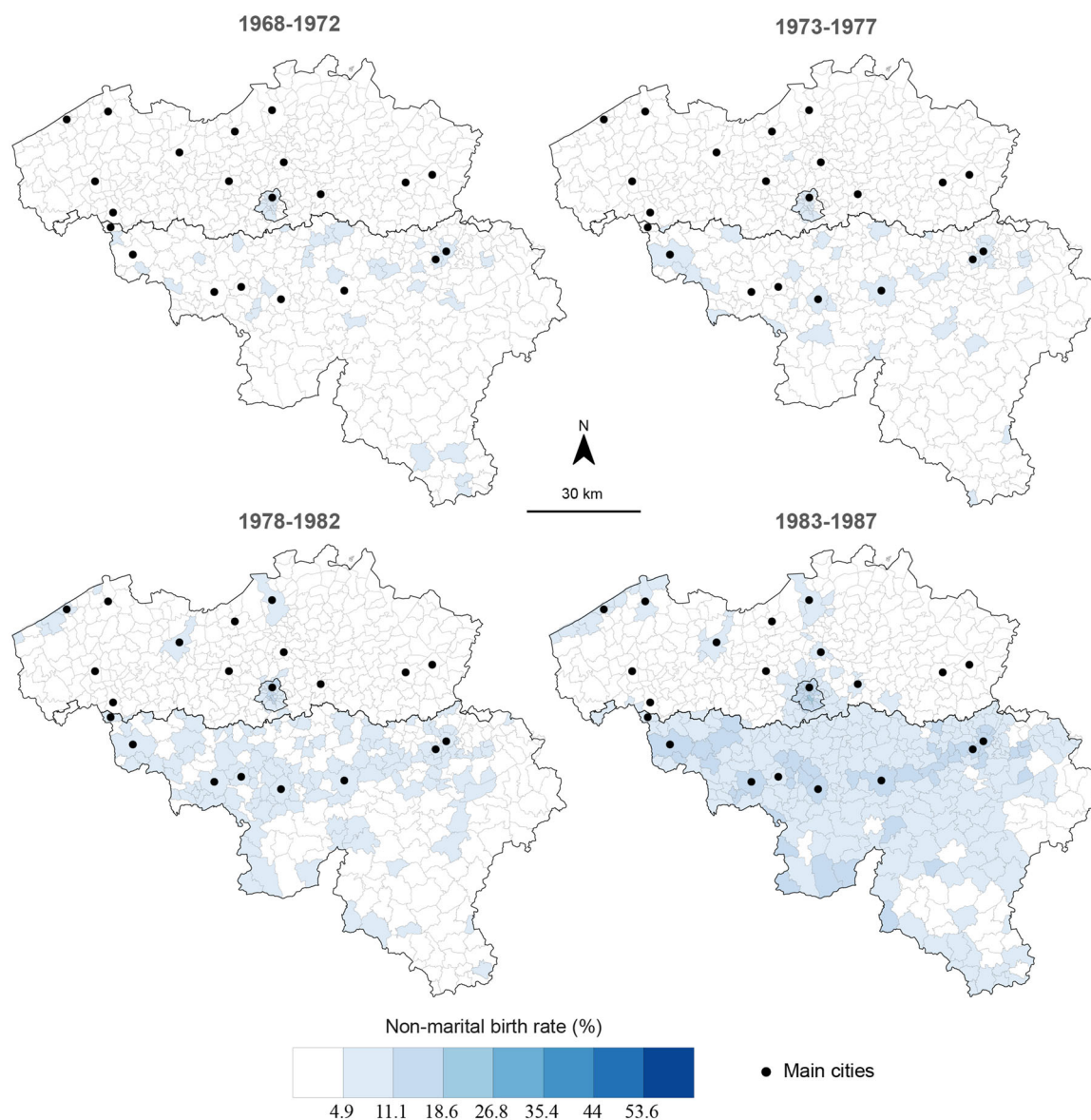
The construction of the database was a very time-consuming process, requiring several months of work. However, it was the only way to obtain a unique and original spatio-temporal database that allows the analysis of the spatial dynamics of non-marital births at the municipal level since the late 1960s. This type of database is very rare in the existing literature on the subject.

Table 1 lists the variables used in this article. Some of the choices and calculations are based on the limitations of the data. The variable of interest is the percentage of nonmarital births (%). The explanatory variables have been chosen to best reflect the factors highlighted by some existing theories. Secularisation,

TABLE 1 | Data Sources.

Variable	Indicator	Data sources
Nonmarital births	Share of nonmarital births (%)	Civil registry/National Register
Secularisation	Share of the votes for the Socialist, Communist and Liberal parties in parliamentary elections (%)	Federal Public Service of the Interior (IBZ)
Urbanisation	Population density = number of inhabitants/area	Population censuses/National Register
Population with high education	Share of the population aged 15 and older who achieved high education (%)	Population censuses
Unemployment	Share of the unemployed men aged 15–64 (%)	National Employment Office (ONEM)
Population structure	Population aged 65 and older/population aged 15–64 (%)	Population censuses/National Register
Sex-ratio of labour market participation	Economic activity rate of women (15–64)/Economic activity rate of men (15–64)	Population censuses
Foreign population	Share of the population without Belgian nationality (%)	Population censuses/National Register

NON-MARITAL BIRTHS IN BELGIUM (1968-1987)



Sources: National register, Civil Registries, Statbel. Authors: Doignon Y., Mbath O. (2025).

FIGURE 2 | Nonmarital Births in Belgium (1968–87).

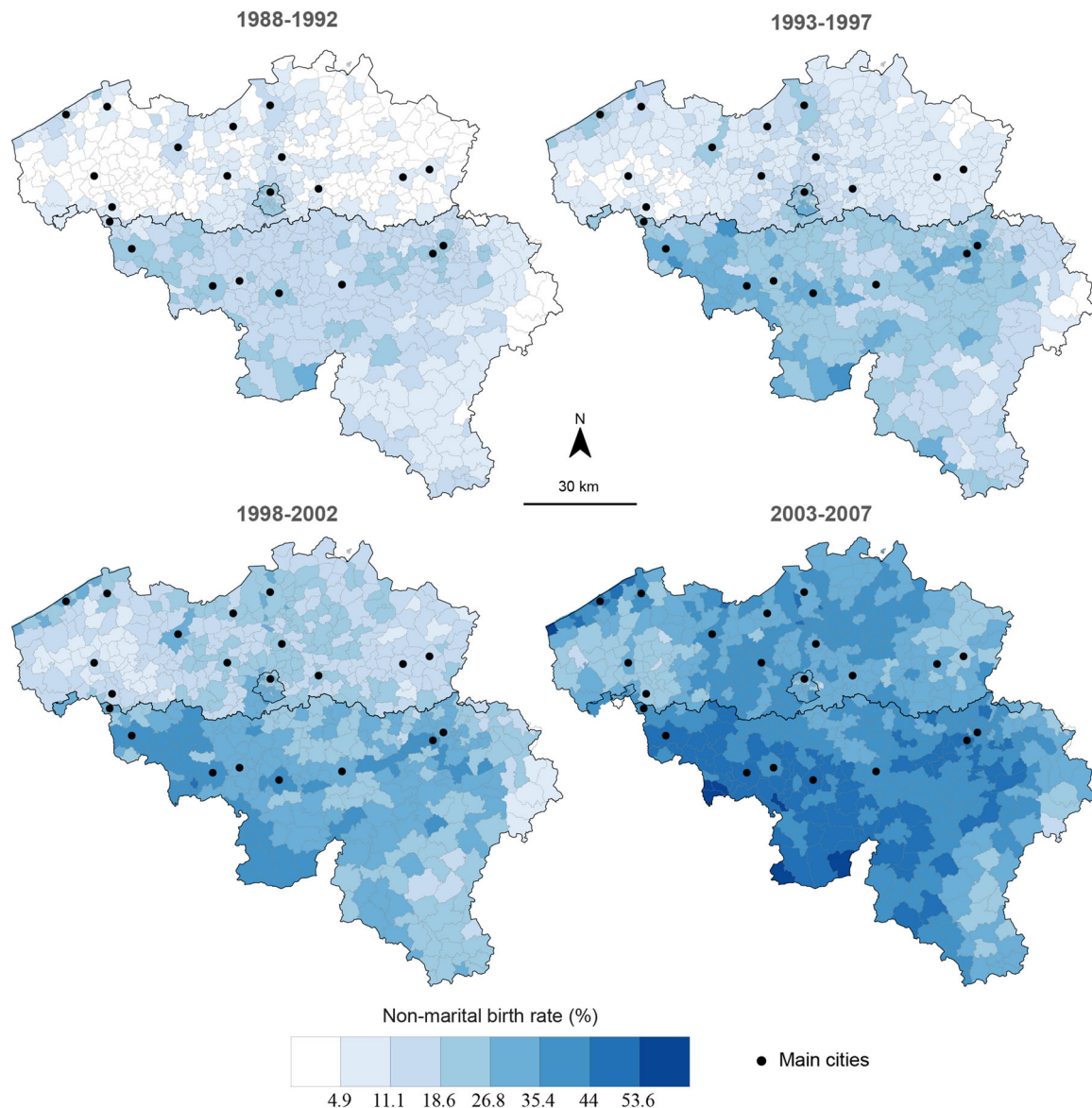
population with higher education and urbanisation represent the *Second Demographic Transition*. Unemployment represents the *Pattern of Disadvantage*, and, in part, the *Globalisation*. The sex-ratio of labour market participation is representative of the *New Home Economics* and an imperfect proxy for the *Gender Revolution*, as it is difficult to obtain data on gender equality in the domestic sphere at the municipal level. Population structure and foreign population are control variables for the composition of the population.

3.2 | Exploratory Descriptive Analyses

Using a series of maps, we show the spatial dynamics of non-marital births in Belgium over a period of 50 years, from 1968 to 2017. In the period 1968–72, they were low, less than 3% for

most of the municipalities, with a maximum around 10% (Figure 2). A slightly higher rate was observed in the Brussels-capital region and in some parts of the French-speaking Wallonia region. Between 1973 and 1977, there was very little change, and most regions remained at a very low level (below 4.91%). Only a few regions exceeded this level, notably the large Walloon cities (Namur, Tournai), particularly industrial ones (Charleroi, Liège), the entire Brussels agglomeration, and municipalities on the border with France (south of Tournai). The first stage in the process of spatial diffusion was observed between 1978 and 1982, when several areas recorded a slight increase in the nonmarital birth rate to over 5%. This diffusion occurred through geographical proximity of the industrial basins and the northern half of Wallonia, especially in large cities such as Mons, Charleroi, Namur, and Liège. These regions were among the most secularised, with the lowest

NON-MARITAL BIRTHS IN BELGIUM (1988-2007)



Sources: National register, Civil Registries, Statbel. Authors: Doignon Y., Mbath O. (2025).

FIGURE 3 | Nonmarital Births in Belgium (1988–2007).

levels of church attendance in the country. Nonmarital births also began to increase in Flanders, especially in the two main Flemish cities (Ghent and Antwerp) and along the coast, and exceeded 5%.

Between 1983 and 1987, nonmarital births continued to spread in the northern half of Wallonia, around Brussels, and along the French border. In Flanders, however, there was no significant spatial diffusion except along the coast and in secondary cities (Mechelen, Leuven).

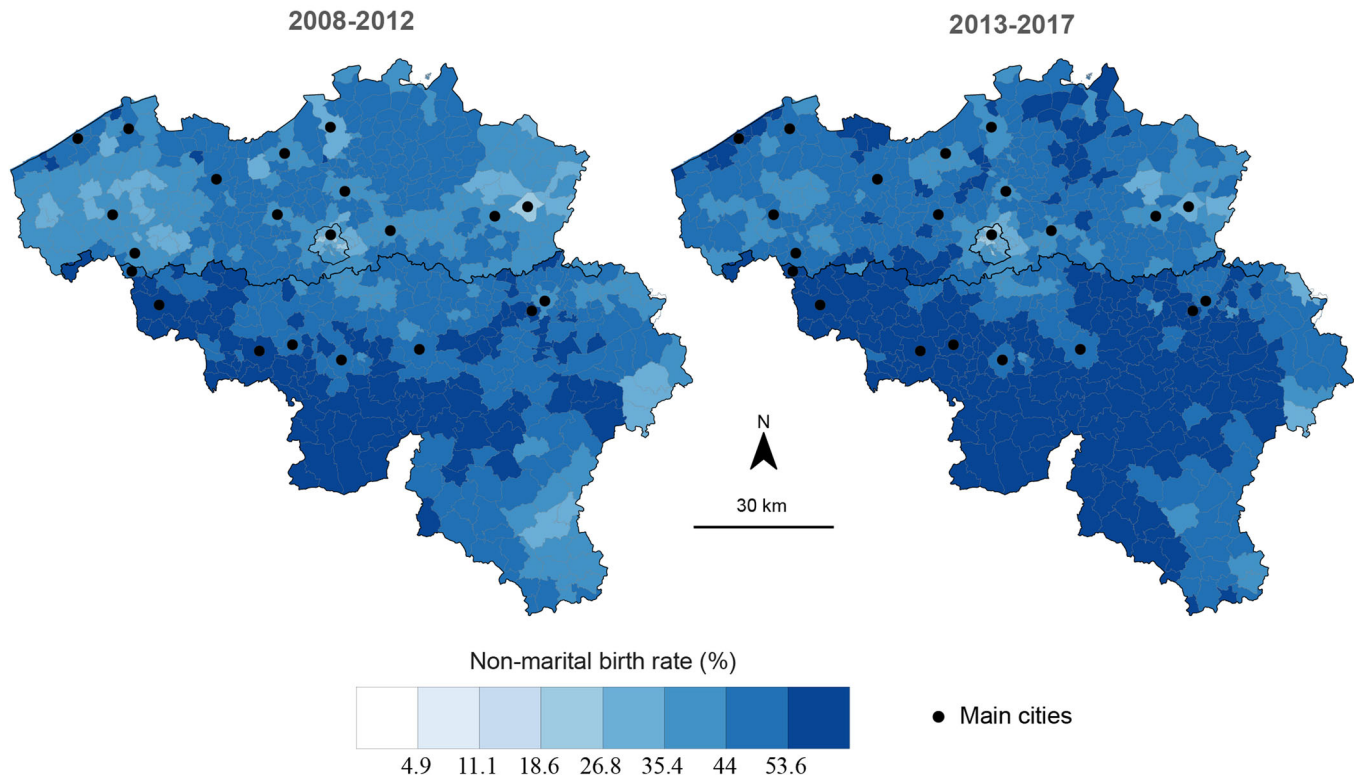
Between 1988 and 1992 (Figure 3), nonmarital births continued to increase around the Brussels agglomeration and in Wallonia, even reaching the more conservative south-eastern part of the country. In Flanders, diffusion began within the Ghent-Antwerp-Brussels triangle and to some extent in the cities of

Limburg. Spatial discontinuities began to increase, especially around Antwerp, Ghent, and Ostend.

In subsequent periods, i.e. from 1993 onwards, nonmarital births continued to spread within the Antwerp-Ghent-Brussels triangle and reached West Flanders, Limburg, and the border region with Luxembourg (Figures 3 and 4). These regions, known for their traditional and conservative nature, were more resistant to family change. Previous research has shown that these regions are less secularised than the rest of Belgium (Lesthaeghe and López-Gay 2013).

From 2013 to 2017, a high level (> 50%) of nonmarital births was gradually observed in Wallonia (Figure 4). During this period, a gradual reversal of the urban-rural relationship is particularly evident in Belgium, with secondary cities and rural

NON-MARITAL BIRTHS IN BELGIUM (2008-2017)



Sources: National register, Civil Registries, Statbel. Authors: Doignon Y., Mbath O. (2025).

FIGURE 4 | Nonmarital Births in Belgium (2008–2017).

areas recording higher rates of nonmarital births than primary cities, which were initially the forerunners. This trend is particularly evident in large urban agglomerations such as Brussels and Antwerp. This phenomenon has been observed for nonmarital births in France (Doignon 2021) and for nonmarital cohabitation in Belgium (Doignon et al. 2020). The descriptive maps show a process of spatial diffusion for the nonmarital births in Belgium.

We also measure the spatial autocorrelation of nonmarital births for each period using the Moran's I. This is a global diagnostic tool for exploratory spatial data analysis that tests whether the value of a variable observed in a given location is independent of the values observed in neighbouring locations (Anselin et al. 2004). In our case, it measures how the nonmarital births (or an explanatory variable) in one municipality are correlated with the same variable in the neighbouring municipalities.

In our study, the Moran's I value¹ for nonmarital births was 0.43 for the period of 1968–72, indicating a moderate level of spatial autocorrelation (Table 2). In the subsequent years, the Moran's I index showed a marked upward trend, reaching 0.75 in 1993–97. This significant increase indicates an increase in spatial autocorrelation; municipalities with high rates of nonmarital births became increasingly clustered. The bell shape of the Moran's I value supports the spatial diffusion perspective (Costa 2015; Vitali et al. 2015). The Moran's I indices for the explanatory variables show a high spatial autocorrelation. While some variables have a stable spatial autocorrelation, such

as population density, others, such as unemployment, have a Moran's I that changes over time.

3.3 | Methods: A Dual Analytical Approach

The descriptive analyses revealed a process of spatial diffusion of nonmarital births, but also a strong spatial autocorrelation in the data – both for the dependent variable and for the independent variables. This shows that nonmarital birth rates in a given municipality seem to be influenced by the rates in neighbouring municipalities in the preceding period. This is an interaction between space and time, where areas are more likely to see an increase in nonmarital births if nearby areas have already seen an increase in these phenomena. These factors mean that conventional regressions would be biased and not suitable for modelling this type of phenomenon (Anselin et al. 2004). To take these different elements into account in our analyses, we decided to use spatial modelling.

We have used two types of analytical approaches, one for each research question. The first is to use a panel model, which take into account spatio-temporal interaction, to measure the spatial diffusion effect throughout our study period (1968-2017). The second is to use cross-sectional models that measure the spatial variation in each period, that is, the factors that explain why the nonmarital births rate is high or low in a given region in a given period. By comparing the results of all these cross-sectional models, it is possible to analyse whether the main drivers change over time.

TABLE 2 | Moran's I for dependent and independent variable.

Period	Nonmarital Births		Population density	Sex-ratio of labour market participation	Population with high education	Old-age dependency ratio	Foreign population	Male unemployment rate
	Births	Secularisation						
1968–1972	0.43	0.86	0.61	0.52	0.45	0.71	0.59	0.67
1973–1977	0.55	0.85	0.62	0.54	0.48	0.69	0.6	0.64
1978–1982	0.62	0.83	0.63	0.58	0.49	0.65	0.6	0.55
1983–1987	0.69	0.82	0.63	0.61	0.53	0.62	0.61	0.59
1988–1992	0.74	0.77	0.63	0.62	0.55	0.56	0.62	0.74
1993–1997	0.75	0.76	0.63	0.62	0.59	0.50	0.65	0.74
1998–2002	0.70	0.80	0.63	0.60	0.61	0.42	0.67	0.75
2003–2007	0.65	0.85	0.62	0.58	0.61	0.43	0.68	0.76
2008–2012	0.66	0.89	0.62	0.50	0.61	0.46	0.68	0.73
2012–2017	0.68	0.88	0.63	0.35	0.61	0.49	0.69	0.75

This provides a comprehensive overview of the spatial dynamics of nonmarital births in Belgium. To use an analogy, each cross-sectional model is like a photograph. By piecing together several of these photographs, it is possible to reconstruct the film (i.e. the spatial dynamics).

3.3.1 | Dynamic Spatial Durbin Model to Measure the Spatial Diffusion Effect

Although the maps (Figures 2, 3 and 4) and the evolution of Moran's I (Table 2) show a spatial diffusion pattern, they alone do not allow us to claim that there is a spatial diffusion effect, because the pattern observed on the maps could be produced by other underlying phenomena. We need to use a statistical model and control for the spatial diffusion effect by other factors. To do this, we choose the Dynamic Spatial Durbin Model (DSDM), which is an extension of the Spatial Panel Durbin Model (panel model), which in turn is the panel version of the Spatial Durbin Model (cross-sectional model). We will explain these three models, starting with the simplest.

Spatial econometrics has been developing spatial regression for several decades. The principle is to integrate at least one spatial lag into the equation of a classical linear regression. A spatial lag is, for a given region, the mean value of the variable in the neighbouring regions (neighbourhood defined by a spatial weight matrix). Depending on the spatial lag terms introduced into the equation, six cross-sectional spatial regressions are considered as 'classical' in spatial econometrics, including the Spatial Durbin Model (SDM) (Loonis 2018). This is a spatial regression model that takes into account the effect of the spatial lags on both the dependent and the independent variables. This means that the level of nonmarital births in a region is modelled by its own characteristics and those of neighbouring regions. The SDM equation is:

$$Y_i = \alpha + \rho WY_i + X_i\beta + \theta WX_i + \varepsilon_i \quad (1)$$

Where,

- Y_i : the dependent variable (nonmarital births) for i^{th} municipality
- α : the constant
- W : the spatial weight matrix
- X_i : the vector of explanatory variables for i^{th} municipality
- WY_i : the spatial lag of the dependant variable–i.e. the mean value of the nonmarital birth rate of the neighbouring municipalities of the municipality i
- WX_i : the spatial lag of the explanatory variables–i.e. the mean value of a variable X of the neighbouring municipalities of the municipality i
- β : the vector of coefficients for the explanatory variables
- ρ : the spatial autocorrelation coefficient for the dependent variable
- θ : the spatial lag coefficient for the explanatory variables
- ε_i : the error term

The SDM has been transformed into a panel model, which allows the modelling to cover several years or periods. In its fixed effects version, the general form of the Spatial Panel Durbin Model is given by the equation:

$$Y_{it} = \alpha + \rho WY_{it} + X_{it}\beta + \theta WX_{it} + \mu_i + \varepsilon_{it} \quad (2)$$

Where,

- Y_{it} : the dependent variable (nonmarital births) for i^{th} municipality at time t
- α : the constant
- W : the spatial weight matrix
- X_{it} : the vector of explanatory variables for i^{th} municipality at time t
- WY_{it} : the spatial lag of the dependant variable–i.e. the mean value of the nonmarital birth rate of the neighbouring municipalities of the municipality i at time t
- WX_{it} : the spatial lag of the explanatory variables–i.e. the mean value of a variable X of the neighbouring municipalities of the municipality i at time t
- β : the vector of coefficients for the explanatory variables
- ρ : the spatial autocorrelation coefficient for the dependent variable
- θ : the spatial lag coefficient for the explanatory variables
- μ_i : the entity-specific effect
- ε_{it} : the error term

In this panel spatial model, the coefficient ρ has sometimes been interpreted as a spatial diffusion coefficient (Vitali et al. 2015; Brée and Doignon 2022). It may indeed partly reflect a process of spatial diffusion. However, it is not really a spatial diffusion coefficient in the strict sense, as this model does not measure the effect of the nonmarital birth rates of neighbouring regions in the previous period. This model is static, as all the parameters are indexed by t , and does not include a spatio-temporal lag term that measures the spatial diffusion effect after controlling for the explanatory factors. Therefore, we use the dynamic version of the Spatial Durbin Model (DSDM). It extends traditional panel data models by incorporating spatio-temporal lags of the dependent variable (Elhorst 2012). Thus, the form of the DSDM is:

$$Y_{it} = \alpha + \tau Y_{it-1} + \vartheta WY_{it-1} + \rho WY_{it} + X_{it}\beta + \theta WX_{it} + \mu_i + \varepsilon_{it} \quad (3)$$

Where,

- Y_{it} , α , W , X_{it} , WY_{it} , WX_{it} , β , ρ , θ , μ_i , ε_{it} are defined as the previous equation
- ϑWY_{it-1} : the spatial diffusion effect (spatio-temporal lag)–i.e. the mean value of the nonmarital birth rate of the neighbouring municipalities of the municipality i at time $t-1$
- τY_{it-1} : the time lag–i.e. the nonmarital birth rate of the municipality i at time $t-1$

The dynamic nature of this model allowed the examination of both spatial and temporal lag effects, showing how nonmarital births in a municipality at time t are correlated with the nonmarital birth rates in neighbouring municipalities from the previous time ($t-1$). The inclusion of spatio-temporal lag terms allows for the explicit measurement of spatial diffusion effects due to geographical proximity. This model is therefore suitable for answering our first research question. Moreover, this model is very original, as to our knowledge it has almost never been used to study the spatial dynamics of a family change, with the exception of a very recent study on late fertility in Europe (Setz et al. 2025).

The model shown above is a fixed effects (FE) model. However, it is possible to use a random effects (RE) model. FE models account for unobserved heterogeneity by allowing each region to have its own intercept, which is useful for studies involving adjacent spatial units within a defined area, such as all regions in a country (Elhorst 2005). This is particularly relevant in our case, as it captures the unique characteristics of each region and reduces omitted variables bias (Greene 2005). In fact, a fixed effects model is particularly appropriate when the study area covers the entire population of interest (Yang et al. 2006). In addition, FE models require a sufficiently large time dimension (T) to consistently estimate individual effects, and cannot estimate variables that do not vary over time. On the other hand, random effects models assume that individual-specific effects are uncorrelated with the explanatory variables, a restrictive and often unrealistic assumption (Baltagi et al. 2003). Moreover, RE models are less suitable for contiguous study areas where spatial weight matrices are critical for defining spatial relationships. We therefore use a fixed effects model. As with other spatial regressions using the ρ parameter, the parameter estimates in DSDM cannot be interpreted because they do not take into account the effect of feedback loops. It is necessary to calculate the direct, indirect and total impacts, which are interpreted based on the partial derivatives (Debarys et al. 2012; Vitali et al. 2015). In simple terms, direct impacts are the effect of a variable in a region i on the same region i , the same as in a classical regression. Indirect impacts are the effect of a variable in the neighbouring regions of region i on that region i (spatial spillovers). The total impact combines both effects, providing a comprehensive measure of spatial interactions. The DSDM provides an advanced framework for a comprehensive analysis of the spatial dynamics of nonmarital births in Belgium and answer our first research question. However, there are several reasons why we can no longer use this model to answer our second research question. In a panel model, the parameters are an average effect over all periods. They can hide different effects of a variable in different periods. This does not allow us to identify the changing effect of the explanatory variables. For example, the model cannot measure whether unemployment or secularisation has the same effect on nonmarital births over time, or whether the effect is higher or lower in one period than in others. This can be investigated by calculating total effects as a function of period, or by estimating a model with interactions between variables and period. We have tried both techniques, but we have encountered significant challenges related to convergence issues. Indeed, there are too many parameters included in the model and the number of municipalities is too small. The estimation process may struggle to find a stable and accurate

municipalities over time. This high value means that non-marital births are not randomly distributed, but shows substantial clustering, and that they do not occur in isolation, but are correlated with the behaviour of neighbouring areas.

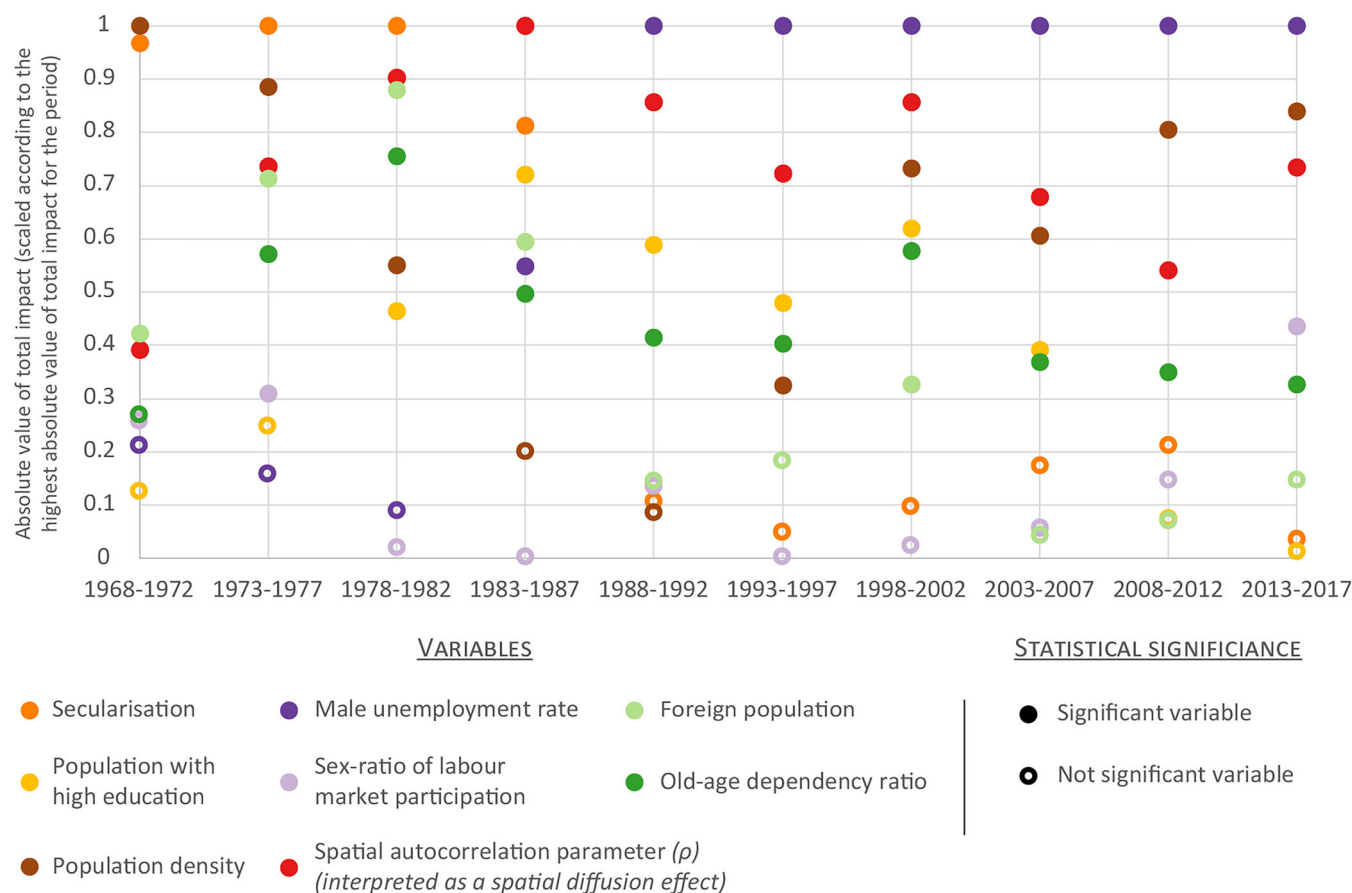
The reported spatial diffusion effect (δ) is 0.14 and significant. This means that an increase in the nonmarital birth rate in the neighbouring municipalities in the previous period leads to an increase in the nonmarital birth rate in the reference municipality in the current period. This finding highlights the process of spatial diffusion, whereby nonmarital births diffuse from one municipality to adjacent ones over time, controlling for other factors. This spatial diffusion effect suggests the role of geographical proximity in the spread of social behaviours. The temporal lag coefficient is 0.29 and reflects temporal dependence, suggesting that past levels of nonmarital births have a positive and significant influence on current levels. The strong spatial autocorrelation and diffusion effects highlight the importance of geographical and temporal factors in understanding the spatial dynamics of non-marital childbearing in Belgium from 1968 to 2017.

The result shows that a spatial diffusion effect remains even when other covariates are included in the model. However, this does not mean that this effect is the only one that explains the level of nonmarital births in the municipalities. The selected

covariates also have an effect. The results show that the situation is not binary (spatial or other factors) and that spatial effects combine with socioeconomic factors.

4.2 | Evolution of Main Explanatory Factors

In this section, we present the evolution of the main determinants by the ranking of total impact of each determinant on nonmarital births over different time periods (Figure 5). This ranking provides a nuanced understanding of how each determinant contributes to the evolution of nonmarital births, depending on the stage of the diffusion process. In this model, the spatial autocorrelation coefficient (ρ) is not time-lagged; therefore, it measures the effect of the nonmarital birth rate of neighbouring regions during the same period, not in the previous period. It cannot be interpreted strictly as a spatial diffusion effect. However, given that we measured a spatial diffusion effect using the DSDM in the previous results, it is reasonable to consider that the spatial autocorrelation coefficient (ρ) to be a proxy for the spatial diffusion effect in this model. This is ultimately similar to the way in which studies interpret the spatial autocorrelation coefficient (ρ) in a spatial panel Durbin model as a spatial diffusion effect in the absence of a time lag (Vitali et al. 2015; Brée and Doignon 2022). This allows us to consider the



Interpretation: Between 1968 and 1972, population density was the variable with the highest total impact, with a value of 1 on the y-axis. During the same period, the absolute value of the total impact of secularisation was 95% of that of population density, giving it a value of 0.95 on the y-axis.

FIGURE 5 | Ranking of the factors affecting nonmarital births during different time-period.

spatial autocorrelation (and, indirectly, spatial diffusion effect) as a factor in the same way as other socioeconomic variables.

In the initial phase (1968–1972), urbanisation and secularisation are identified as the most correlated factors. This finding highlights the role of urban and secularised areas as pioneers in the early diffusion of nonmarital births in Belgium, a result quite consistent with the SDT. Although the spatial autocorrelation (ρ) and the proportion of foreigners are significant, they are twice as weakly correlated with nonmarital births as urbanisation and secularisation. All other covariates are insignificant. The 1973–1982 period shows almost the same ranking, but secularisation becomes the most important factor, followed by urbanisation, spatial autocorrelation (ρ) and the proportion of foreigners. Secularisation remains the most important factor until the period 1978–1982 (included), after which its effect begins to decline, i.e. when the effect of unemployment begins to increase. The spatial autocorrelation parameter (ρ) and the proportion of foreigners move closer to secularisation to become the three main factors. The importance of urbanisation decreases continuously from 1973 to 1977 and becomes insignificant in the period 1983–1987. These trends reflect the fact that nonmarital births are no longer confined to towns and cities, but have diffused beyond the urban areas of Wallonia and Brussels.

From 1988 to 1992, three factors stand out, to a greater or lesser extent depending on the period: unemployment, spatial autocorrelation (ρ) and urbanisation. Unemployment emerges as the most important determinant, and remains in first place in subsequent periods. This result supports the *Pattern of Disadvantage* and *Globalisation*. It is consistent with the findings of a previous study in Norway (Vitali et al. 2015). However, this does not mean that secularisation is no longer an important determinant. Indeed, the most secularised regions in Belgium, such as the Walloon coalfields (Mons, Charleroi, Liège), have been among the most affected by unemployment since the 1980s. It is therefore possible that there is a confounding effect in the models, as it is difficult to distinguish precisely between the effects of the two variables in Belgium. However, unemployment seems to have been the most important variable for nonmarital births since the late 1980s. Over time, spatial diffusion (as measured by the spatial autocorrelation parameter) becomes a more important factor. From 1978 to 1982 to 2003–2007, it was consistently in second place in terms of effect, suggesting its crucial and persistent role in shaping family changes over time. This is not surprising, since nonmarital births was diffusing throughout Wallonia in the 1980s and began to diffuse to Flanders (late 1980s). Urbanisation re-emerged as an important factor from the period 1998–2002, when the urban hierarchy was reversed and the nonmarital birth rate in large cities began to fall below that in lower ranking cities or rural areas. This shift highlights the importance of the socioeconomic dimensions in the diffusion process of the nonmarital births.

The share of foreigners is only an important factor in the 1970s–1980s. In line with the SDT, higher education has a positive effect. It was an important factor from the 1980s until the end of the 1990s. Outside of this period, however, it was a minor and often insignificant factor. Surprisingly, the sex-ratio in the labour market does not really emerge as a particularly important factor. Ultimately, it is not closely correlated with nonmarital births. Regions with a small gap between female and male labour market participation can

be found in Flanders, Brussels and Wallonia. This contrasts with the spatial pattern of nonmarital births, which were initially concentrated in Brussels and Wallonia before spreading to Flanders.

The visual ranking of determinants over time provides valuable insights into the complex interplay of factors driving the increase in nonmarital births. This approach captures the dynamic contributions of various explanatory factors, alongside the persistent spatial effect and shows how these elements collectively shape trends in nonmarital births throughout the spatial dynamics.

5 | Discussion and Conclusion

In this article, we analyse the spatial dynamics of nonmarital births in Belgian municipalities over a 50-year period (1968–2017). The descriptive maps and Moran's I statistics show a pattern of spatial diffusion. This finding is consistent with the evidence from previous studies, which collectively suggest that spatial diffusion plays a central role in shaping the geography of family changes (Vitali et al. 2015; Bleha and Ďurček 2019; Caltabiano et al. 2019; Doignon et al. 2020, 2022; Doignon 2021; Setz et al. 2025). We used the Dynamic Spatial Durbin Model to disentangle the spatial diffusion effect from other factors, i.e. measure whether the observed spatial dynamics are primarily driven by the spatial diffusion effect or whether other factors play a significant role. Our results highlight a significant spatial diffusion effect, indicating that socioeconomic factors alone are insufficient to explain the spatial dynamics of nonmarital births in Belgium (H1 confirmed). Furthermore, when ranking the explanatory variables, the spatial autocorrelation value (interpreted as a diffusion effect) consistently emerged as one of the top determinants, confirming its critical role in influencing the diffusion of nonmarital births. Our research highlights the spatial diffusion effect as a key and critical factor in understanding family changes, as it provides information that other socioeconomic factors do not. It contributes to the broader theoretical debate on family changes by suggesting that diffusion mechanisms should be mobilised to a greater extent than at present, as has been done for the fertility transition (Casterline 2001).

This study is pioneering in its use of the DSDM to measure the spatial diffusion effect of a family change. By incorporating both spatial and temporal lag, our methodology provides a comprehensive understanding of how nonmarital birth rates are influenced by neighbouring regions. This approach allows us to explicitly quantify how demographic behaviour diffuse spatially, providing a significant methodological contribution and new insights to population sciences research. The local geographical level and the extended time period of 50 years used in this study also represent a strong empirical originality. This has allowed us not only to describe and study in detail the spatial diffusion of nonmarital births since the beginning of the process, which is rarely done in the literature, but also to identify and quantify the magnitude of the factors influencing these spatial dynamics and rank them accordingly for different time periods.

The spatial dynamics of nonmarital births in Belgium over the last fifty years provide a compelling examination of how this behaviour has evolved spatially. The spatial dynamics of nonmarital births

have been analysed in terms of various factors that represent different theoretical frameworks. We have identified several main drivers, but most importantly, our findings indicate that the main drivers are evolving over time (H2 and H3 confirmed). No single theory can fully explain the spatial dynamics of nonmarital births, with each theory having relevance depending on specific temporal stages of the diffusion process.

Several theories have been put forward to explain the spatial dynamics of nonmarital births in Belgium over time. Our results support the SDT, as we find a positive association between nonmarital births on the one hand, and the secularisation and urbanisation (and to a lesser extent, women's higher education) on the other. However, we see that the effect of secularisation in explaining the increase in nonmarital births was strong in the early stages, but seems to be less important in the later stages (from the late 1980s).

Our findings also show a strong effect of unemployment. This effect has increased over time, highlighting its role in the diffusion of nonmarital births. Since the late 1980s, unemployment has emerged as the most important determinant, consistent with the *Globalisation* and the *Pattern of Disadvantage* in which nonmarital births are argued to be higher among people of lower socioeconomic status (Perelli-Harris et al. 2010). Unemployment and job insecurity are generally thought to lead cohabiting couples to postpone marriage due to the high costs associated with marriage, thereby increasing the nonmarital births since the modern times (Abrahamson 2000; Perelli-Harris and Gerber 2011; Klüsener et al. 2013).

However, the theories of the *New Home Economics* and the *Gender Revolution* do not seem to offer a satisfactory explanation for the geographical distribution of nonmarital births in Belgium. In the early stages, cultural (secularisation), urban and educational dimensions played a more important role than economic dimension. As the latter became more significant, its impact was more closely associated with economic uncertainty (unemployment) than with women's participation in the labour market.

The main limitation of this study is the fit of the variables used to the theories. It can be difficult, if not impossible, to find the perfect proxy for a theory spanning a 50-year period at the municipal level. Other explanatory factors would have been useful, but are unfortunately not available. This is particularly true of the *Gender Revolution*, which is especially challenging to quantify at a local level. In our models, this theory is represented by the variable 'sex ratio of labour market participation', reflecting inequality in the public sphere (the labour market). Ideally, we would also have included a variable representing the private domestic sphere, such as men's involvement in domestic work. While this information is available in surveys, they are often not representative at the local level, let alone over a 50-year period. Additionally, we used election results as a proxy for secularisation, which is one of the indicators of SDT. It would, however, have been more relevant to have a direct measure of religious practices, such as mass attendance among the population. Such statistics existed at parish level in the 1960s and 1970s but were subsequently stopped. Nevertheless, they did highlight the strong correlation between religious practice and voting patterns during that period. Finally, including a variable on economic insecurity would have enabled us to better substantiate the

theory of *Globalisation*. Despite this limitation, Belgian statistics should be commended for their quality and richness. They benefit from a long tradition of recording socio-demographic and economic phenomena at the municipal level. While the variables derived from these statistics are imperfect proxies for theories, they have the merit of existing and being available over a long period of time at a detailed geographical level.

To summarise, the SDT seems to explain the beginning of the process and the pioneer regions, with secularisation and urbanisation playing an important role. Subsequently, the *Pattern of Disadvantage* and *Globalisation* seem to take over, with unemployment becoming increasingly important, although the regions with high unemployment rates are also among the most secularised. On the other hand, the spatial diffusion mechanism is an explanatory factor as well as the others. In fact, it appears to be a particularly important factor, sometimes even more so than some socioeconomic factors. This aspect has not been emphasised enough in previous studies. This article has therefore shown that a comprehensive understanding of family changes requires the integration of different theoretical perspectives and the spatial diffusion process. Future studies should adopt similar approaches to investigate family changes in other European countries. This would enhance the generalisability and depth of the findings and allow us to determine whether the patterns observed in Belgium are applicable to other countries or to Europe as a whole.

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Conflicts of Interest

The authors have no conflicts of interest.

Endnotes

¹First order contiguity is used as the spatial weight matrix.

²These total impacts are presented in Annex 1.

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Annex 1

Total impacts of the 10 Spatial Durbin Models.

Variable	1968–1972	1973–1977	1978–1982	1983–1987	1988–1992	1993–1997	1998–2002	2003–2007	2008–2012	2013–2017
Secularisation	0.39	0.39	0.39	0.4	0.08	0.04	−0.08	−0.18	−0.25	−0.03
Population density	0.41	0.35	0.22	0.1	−0.06	−0.27	−0.64	−0.63	−0.95	−0.69
Sex-ratio of labour market participation	0.11	0.12	0.01	0.00	−0.1	0.00	0.02	−0.06	−0.17	−0.36
Population with high education	0.05	0.1	0.18	0.35	0.44	0.4	0.54	0.41	0.09	0.01
Old-age dependency ratio	0.11	0.22	0.3	0.24	0.31	0.34	0.5	0.38	0.41	0.27
Foreign population	0.17	0.28	0.35	0.29	0.11	0.15	0.28	−0.05	−0.08	−0.12
Male unemployment rate	0.09	−0.06	0.04	0.27	0.75	0.83	0.87	1.04	1.19	0.82
ρ parameter (interpreted as a spatial diffusion effect)	0.16	0.29	0.36	0.49	0.64	0.6	0.74	0.7	0.64	0.6