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Diffusion effects in the Belgian fertility transition

Space-time analyses at the municipal and individual levels (1887–1934)

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Introduction

In the course of the last two centuries, European populations experienced deep transformations in family behaviours. Between the late nineteenth century and early twentieth century couples began to deliberately limit their number of births, leading to an unparalleled decline in fertility levels (Coale and Watkins, 1986). At the same time, marriage became universal and was celebrated at much younger ages than in the past (Lesthaeghe, 1977). In the 1960s new family trends began to appear. Household formation and childbearing were postponed to older ages. Cohabitation started to figure as a common alternative to marriage, and divorce affected an increasing number of couples (Lesthaeghe and Moors, 2000).

Even though these transformations affected every society in Europe, they did not happen for everyone everywhere at the same time. Changes in family behaviour typically started in a certain group and later spread to the rest of the population (Livi-Bacci, 1986; Sobotka and Toulemon, 2008). From a spatial perspective, these changes first concerned specific places before spreading to the rest of the territory (Watkins, 1990; Lesthaeghe and Neels, 2002).

The underlying mechanisms of the spread of new family trends are still a matter of debate. On the one hand, it could be argued that the determinants of demographic behaviour – such as economic and cultural shifts – do not concern all the groups of society at the same time and do not happen simultaneously in all places. On the other hand, it has been suggested that there is something more behind the patterns of change. Diffusion processes, via the exchange of ideas and information between people, could affect the spread of a new behaviour. In other words, the way individuals interact and are connected in space could influence the rhythm and the geography a behavioural change.

The fertility decline in Europe in the nineteenth and early twentieth centuries – commonly referred to as the European fertility transition – has offered rich ground for this debate. Early studies using aggregate data revealed the remarkable geographic patterns in the spread of the decline among European provinces (Coale and Watkins, 1986). The Belgian case became an emblematic example with Lesthaeghe's thorough analysis of the transition process at the district level and of the impact of the linguistic border on the timing of decline (Lesthaeghe, 1977). However, these studies relied on highly aggregated data available at ten-year intervals. Even though their findings hint that diffusion effects might have played a role, the evidence remains largely indirect.

More recently, local studies have used micro-level historical data in order to investigate the impact of social networks in the adoption of birth control during the fertility transition. In Belgium, diffusion has been assessed at the individual level in the cities of Leuven (Van Bavel, 2004a) and Ghent (Matthys, 2013). These studies offer detailed accounts on how social networks influenced fertility behaviour in a local context. Nonetheless, they fail to grasp the role of diffusion on the global transition process at the scale of the country.

The main purpose of this thesis is to investigate the underlying mechanisms of the spread of modern fertility behaviour in Belgium during the fertility transition. Its premise is to find a compromise between the general approaches at the aggregate level and the local approaches at the individual level. To this end, the research relies on a unique body of data at the scale of the country gathered from different sources, between 1886 and 1934. This body of data offers a high level of spatial and temporal precision and combines macro and micro perspectives. Advanced quantitative methods are employed in order to investigate the impact of diffusion effects on the timing, the pace and the geography of fertility decline.

It is important to bear in mind that this research focuses on the determinants of the *spread* of modern fertility behaviour throughout the transition process, rather than on the determinants of the fertility decline itself. Numerous studies have investigated the causes of the decline in different contexts and from various angles. My attempt in this thesis, in contrast, is to produce a detailed analysis of the course of the transition in space over the years.

The Belgian territory

The Belgian fertility transition provides an outstanding setting for the study of diffusion. First, the circumstances of fertility decline have been largely documented in previous studies using different datasets and methods. Second, the country has remarkable historical data sources that offer the opportunity to perform a detailed investigation of demographic changes in space and time. Moreover, despite its small size the Belgian territory is rich in diversity. It is crossed by a linguistic boundary from west to east, separating Dutch-speaking populations in Flanders and French-speaking populations in Wallonia. Within the linguistic regions, urban and industrial axes contrast with remote rural zones.

The administrative division of Belgium was altered many times over the years. In the late twentieth century a series of territorial reforms fixed the definitive boundaries of regions, provinces, *arrondissements* (or districts), and municipalities, as depicted in figure 0.1[1]. The main level of analysis in this thesis is the current municipal level, with the difference being that it distinguishes the old urban centres from their rural surroundings. The names of provinces, cities and *arrondissements* mentioned throughout the manuscript can be found on the map.

The eleven German-speaking municipalities situated at the German border in the province of Liège (East Cantons) are not taken into account in the analyses. As they were a part of Germany until 1920, they do not figure in Belgian data sources for most of the fertility transition period.

Figure 0.1.: Belgium: current administrative division

[1]Thanks to Didier Willaert from Interface Demography (Vrije Universiteit Brussel) for kindly providing this map.

Overview of the research and organisation of the manuscript

This manuscript contains eight chapters and is organised into three parts.

Part I – Theoretical framework

The first part of the manuscript draws the theoretical framework of the research. It is composed of two chapters. **Chapter 1** brings a literature review of the theoretical and empirical studies on fertility transition, in particular on diffusion processes in fertility decline. Based on the lessons from the literature, **chapter 2** presents the research design of the thesis. It states the main objectives, the key concepts and the hypotheses that guide the methodological choices and the quantitative analyses throughout the thesis.

Part II – Data and methods

The second part discusses how the research framework developed in part I is implemented. This involves namely the choice of the appropriate data and methods in order to attain the thesis' purposes and test the hypotheses.

Despite the remarkable historical sources available in Belgium, the data digitised so far is rather poor for applying fine space-time analyses of the fertility transition. Most of the macro-level data available at a fine geographic level had not yet been compiled prior to this thesis. While micro-level data from population registers have been inputted for local studies, there has been no systematic effort to make individual data available for statistic analysis at the scale of the country. In this context, the construction of datasets was a considerable task.

First, an aggregate dataset was assembled using two complementary sources: the censuses and the *Mouvement de la population et de l'état civil*. Most of the data required manual input. A series of methodological choices had to be made in order to deal with the changing territorial division of Belgium and the randomness caused by small numbers. With the data compiled it was possible to calculate several time series of indicators at a fine geographic level, stretching roughly from 1886 to 1935. In particular, an annual indicator of marital fertility (I_g) could be computed at the municipal level between 1887 and 1934. The aggregate dataset offers thus a high level of spatial and temporal detail of the demographic, economic and cultural landscape in Belgium throughout the fertility transition. **Chapter 3** presents all the steps involved in the construction of the aggregate dataset, from the input of raw data to the calculation of indicators.

The digitisation of micro-level data at the scale of the country is an implausible task for the scope of this thesis. Therefore, an alternative had to be found in order to constitute an individual dataset. The solution consists in using data from retrospective information from the 1981 Population Census, as it is already available in digital format. With the census data it is possible to reconstruct entire reproductive histories of women birth cohorts who participated in the latter part of the fertility transition. The census also provides information on the education level and spatial mobility of women. Furthermore, the micro-level data can be linked to the spatial indicators from the aggregate dataset, in a multilevel perspective. The potential and limitations of the individual dataset are discussed in **chapter 4**.

The aggregate and individual datasets offer many possibilities for the study of diffusion. In order to determine the best quantitative tools to exploit the richness of the data I carried out a brief review of methods in **chapter 5**. This included different fields making analytical use of spatial-temporal patterns and diffusion effects. This review guides the choice of methods that are best suited for the particular aims of the research and the nature of the data.

Part III – Analyses

The body of data gathered for this thesis is used in three complementary quantitative analyses.

Chapter 6 brings a thorough description of the spatial-temporal patterns of fertility decline in Belgium. To this end, different methods for space-time analysis are applied to the annual time series of marital fertility at the municipal level: the observation of maps sequences, the study of the spatial clustering of fertility over time using the Moran's I, and the investigation of space-time clustering though the Knox test.

The descriptive analysis in chapter 6 offers a detailed view of the spatial-temporal logics of the Belgian fertility transition and points out the first hints of diffusion in the transition process. However, in the context of fertility changes that stretch over long periods of time the study of the spreading process alone is not conclusive for diffusion. In order to detect diffusion effects it is essential to control for the space-time changes in other relevant variables that are likely to influence fertility. To this end, two causal diffusion models are conceived in chapters 7 and 8, allowing diffusion effects to be isolated from structural and cultural changes in space and time.

Chapter 7 puts forward a macro-level event-history model. The purpose of the model is to estimate the contribution of diffusion, structural and cultural variables on municipalities' likelihood of starting their fertility transition. This model produces a direct test of diffusion effects and evaluates the contribution of structural and cultural change on the spatial-temporal patterns of fertility decline.

Chapter 8 is based on a multilevel event-history model, using the individual and aggregate datasets. Its aim is to test the effect of macro and micro determinants on women's likelihood of adopting modern fertility behaviour. In particular, this model allows for the investigation of diffusion mechanisms and the interaction between macro variables and individual fertility behaviour.

All the statistics, maps and figures in the thesis were produced with the open-source softwares R (R Core Team, 2015) and QGIS (QGIS Development Team, 2015). The manuscript was typeset using LaTeX.

Part I.

Theoretical framework

Chapter 1.

Literature review

The fertility transition has received a great amount of attention in demographic studies. Since the 1940s an abundant number of theoretical and empirical works have investigated the mechanisms that caused reproductive behaviour to change in virtually every society in the world, leading to substantial decline of fertility levels everywhere.

The early scientific literature of fertility decline was dominated by two main sets of explanations, known as ‘structural’ and ’cultural’ theories. Structural theories considered the fertility transition as a consequence of socioeconomic changes, mainly due to industrialisation and urbanisation. Fertility would decline as couples adapted their family size preferences to new economic conditions. In contrast, cultural explanations focused on the impact of cultural changes on fertility behaviour. These theories attributed the fertility transition to the spread of new values and attitudes towards fertility and the family. In this process of cultural shift, the diffusion of new ideas and innovative behaviours by means of social interactions would have played a major role.

For a long time fertility studies have been polarised along these lines, with structural and cultural/diffusionist explanations being presented as competing theories. Furthermore, even though the notion of diffusion was attached to cultural theories, the early literature lacked a clear definition of what diffusion was and how it operated in the transition process.

Recent studies of fertility decline have nonetheless moved beyond the opposition between structural and cultural theories. New theoretical and empirical models have increasingly regarded both economic and sociocultural factors as reinforcing – rather than competing – explanations of fertility decline. At the same time, increasing attention has been given to the role of diffusion in the transition process. Since the 1990s a series of studies have integrated comprehensive theoretical frameworks to model the impact of social interactions on the course of the transition. During the last decade in particular, diffusion has gained renewed interest in fertility studies following the availability of new historical datasets.

The purpose of this chapter is to review the theoretical and empirical literature of fertility transition and diffusion. It is out of the scope of this chapter to discuss in detail the many theories of fertility decline developed since the twentieth century – which has been thoroughly done in a number of literature reviews (Szreter, 1993; Kirk, 1996; Reher, 2004). Instead, I focus on the literature about diffusion and the spatial-temporal patterns of fertility change in order to draw the theoretical foundations of the research design.

The chapter is organised into four sections. The first section briefly presents the essence of the two dominant theories of fertility decline – structural and cultural/diffusionist. In particular, it covers the main misconceptions in the early literature, which have been addressed in more recent studies. Section 1.2 focuses on the diffusion theories in fertility studies developed since the 1990s. The third section presents a review of the empirical contributions on diffusion effects in fertility change in different contexts. The final section draws together the theoretical and empirical literature from the chapter in order to discuss what is known and not known about diffusion processes in the context of the Belgian fertility transition.

1.1. The main theories of fertility decline

1.1.1. Structural theories

Initial attempts to explain the underlying causes of fertility decline date back to the formulation of the 'Demographic Transition Theory' by Notestein (1945) and Davis (1945) (Szreter, 1993; Kirk, 1996). This theory assumed that the fertility transition was one of the many components of the modernisation process and that every society would eventually experience fertility decline once they reached a certain level of socioeconomic development (Bongaarts and Watkins, 1996).

The principle connecting modernisation and fertility decline is that socioeconomic development would have changed the costs and benefits of childbearing, altering therefore individuals' preferences in respect to family size. A general narrative of the mechanisms of change can be described as follows (Szreter, 1993; Bongaarts and Watkins, 1996; Kirk, 1996; Casterline, 2001; Reher, 2004; Alter and Gutmann, 2005). Societies in the past were marked by larger families, with couples bearing a higher number of children. Not only were children useful as labour force (e.g. for the household's farming), but they also had an important role in providing care for their relatives during their old life. As modernisation unfolded, industrialisation and urbanisation created a new economic environment, in which there were fewer opportunities for children to work. Besides, new forms of individual and public savings allowed to considerably reduce the dependency of the elderly upon their younger relatives. Changes in the law such as the establishment of compulsory education and the interdiction of child labour gradually redefined the role of children inside the family and in the society. Childbearing became economically disadvantageous under all these new, 'modern' circumstances. In addition, the improvements in child survival in the modernisation process implied that couples had to bear less children in order to attain their desired family size (Easterlin and Crimmins, 1985; van de Walle, 1986; Galloway et al., 1998; Reher, 1999). As a result of all these structural shifts couples progressively chose to limit their number of children.

These ideas are at the core of what the literature came to call 'structural theories' of fertility transition[1]. They were further developed in many microeconomic models[2] and aggregate studies in different contexts, covering the historical transitions in Europe and North America and contemporary transitions in developing countries.

What these studies have in common is the premise that fertility decline occurs as individuals adapt their childbearing decisions to new socioeconomic circumstances produced by structural shifts (Cleland and Wilson, 1987; Palloni, 2001). Furthermore, structural theories implicitly assume that fertility behaviour is a result of individuals' rational decisions based on the costs and benefits of childbearing. Whereas individuals in the past would deliberately choose to have large families, during the transition individuals would increasingly limit – again deliberately – their number of births based on new calculations of costs and benefits.

1.1.2. Cultural and diffusionist theories

Structural theories of fertility decline began to be questioned in the 1970s following the European Fertility Project's (EFP) findings. The project, conducted by Coale at Princeton University, was the first large-scale attempt to analyse fertility decline in Europe (Coale and Watkins, 1986).

Using indirect techniques to estimate fertility levels[3] the project managed to compile a remarkable dataset of fertility indicators on 600 European provinces from 1870 to 1960. The resulting series of books and articles gathered in the EFP suggested that socioeconomic indicators were not the best predictors of the timing of onset of fertility decline in Europe. Rather, fertility decline spread within clusters of contiguous provinces sharing similar cultural and linguistic features, despite great differences in socioeconomic development levels (Knodel and van de Walle, 1979).

These findings gave support to alternative explanations of fertility decline in opposition to strictly structural views. In particular, the EFP results were used as evidence of diffusion, i.e. the notion that marginal attitudes, ideas or knowledge related to fertility became prevalent through the spread from one individual to another within societies – from the elites to lower classes (Livi-Bacci, 1986) – and in space – from forerunning

[1]The term 'adaptation' has also been used in the literature. This is in reference to the hypothesis that individuals adapt their fertility decisions to structural changes.

[2]See Cleland and Wilson (1987).

[3]See chapter 3, section 3.3 for more details on the indirect indicators used in the European Fertility Project.

spots to laggard regions (Lesthaeghe, 1977). Diffusion would be the key to explain why the cultural geography of Europe seemed to be so important in the timing of transition, and why linguistic and cultural boundaries were found to slow down the spread of birth control (Watkins, 1986; Cleland and Wilson, 1987).

Early interpretations of the EFP findings associated fertility decline with the diffusion of birth control techniques (Knodel and van de Walle, 1979)[4]. In fact, an important premise in the project was that birth control was not practised prior to the decline: fertility intensity was supposed to be at its natural, uncontrolled levels. Fluctuations in fertility were thought to be mainly due to biological factors (such as breastfeeding practices) and nuptiality. In this context, contraception knowledge would be a true innovation that disseminated among individuals and led couples to limit their number of births.

However, the most prominent interpretations of the EFP findings emphasised the diffusion of new values and attitudes towards fertility. The spread of fertility decline would be the result of an important 'ideational change', i.e. a shift from a traditional and religious frame of reference towards new values that made birth control morally acceptable (Lesthaeghe, 1983; Cleland and Wilson, 1987; Lesthaeghe and Surkyn, 1988). The Belgian case became an emblematic example through Lesthaeghe's monograph (1977). He demonstrated that the causes of the earlier transition in Wallonia, compared to Flanders, could not be solely attributed to its early industrial development. In fact, the geography of fertility decline in Belgium was closely linked to that of secularisation and individuation. Just as new attitudes towards the Catholic Church spread first within the French-speaking part of Belgium, so did fertility control spread everywhere in Wallonia. The linguistic border had a clear barrier effect on the penetration of secularisation and birth control in Flanders, where the fertility transition started considerably later.

1.1.3. Polarisation and misconceptions in the early literature

Structural and cultural/diffusionist theories were quickly regarded in the literature as incompatible explanations of fertility decline (Lesthaeghe and Neels, 2002). Carlsson (1966) was the first one to present 'diffusion' and 'adaptation' as competing hypothesis. He argued that fertility decline in Sweden was a consequence of couples' adaptation to new child survival conditions, rather than to the diffusion of contraception knowledge and acceptance.

Later, several studies cast doubt on the EFP findings, arguing that flaws in the project's methods had downplayed the role of socioeconomic variables and attributed too much importance to cultural factors.

A first theoretical consideration concerns the EFP assumption that fertility was at 'natural' levels before the transition. The indirect fertility indicators computed for the

[4] See also Casterline (2001).

project were based on this assumption. In having a pre-transitional natural fertility level as a standard reference, the project would have overlooked important fluctuations in fertility levels in the past due to breastfeeding practices, and excluded the possibility that deliberate fertility control could already exist prior to the transition (Kirk, 1996). As a consequence, the indicators used in the analysis would be inaccurate to determine the timing of onset of fertility transition (Guinnane et al., 1994).

Secondly, the data used in the project were criticised for their high level of aggregation. Because most of the spatial data were only available at the provincial level, significant socioeconomic variables operating at lower levels would have been concealed in the analyses (Brown and Guinnane, 2002).

Finally, a methodological remark is that the quantitative methods used in the EFP were not sophisticated enough and that most evidence simply relied on maps and elementary correlations (Brown and Guinnane, 2007). A number of empirical studies using alternative methods and indicators suggest that socioeconomic changes had a predominant role in the fertility transition, leaving little room for cultural and diffusionist explanations (Richards, 1977; Benavente, 1989; Galloway et al., 1994; Brown and Guinnane, 2002, 2007; Schellekens and van Poppel, 2012).

The main outcome of this debate was an enduring polarisation in the literature, opposing structural and cultural/diffusionist theories of fertility decline. This dichotomisation was crystallised into two long-lasting misunderstandings: an opposition between culture and economics (Lesthaeghe and Vanderhoeft, 2001), as well as a confusion about what diffusion is and to what extent it is linked to cultural change (Palloni, 2001).

The first misunderstanding is that culture and economics provide rival explanations of fertility decline. In an article summarising the EFP findings Coale (1973) clearly stated that, for fertility decline to occur, three preconditions had to be met: birth control had to be advantageous for households (economic precondition), morally acceptable (cultural precondition), and feasible (technical precondition). In other words, both economic and cultural change were said to be essential for fertility transition to take place. What most EFP studies suggested was that cultural change was what *shaped the timing and the pace of fertility transition*; this is not to say, however, that economic development was not a requirement for fertility decline to occur (Lesthaeghe, 1977; Watkins, 1986; Lesthaeghe and Neels, 2002). Recent empirical studies using new data have shown, indeed, that both structural changes and cultural shifts worked as reinforcing causes of fertility decline (Woods, 1987; Van Bavel, 2004a; Breschi et al., 2013, 2014; Dribe and Scalone, 2014; Dribe et al., 2014; Goldstein and Klüsener, 2014; Murphy, 2015).

The second misunderstanding comes from a confusion of what diffusion is. Following the European Fertility Project diffusion has been considered a natural component of 'cultural models', and as incompatible with structural views (Palloni, 2001). In fact, the early literature had long associated diffusion to the spread of immaterial matters, such as contraceptive knowledge and new values about fertility. However, diffusion often concerns the dissemination of ideas and attitudes about material conditions. This includes the perception of the economic environment and the strategies to cope with structural changes in terms of reproductive choices. As argued by Casterline (2001, p. 12), 'A divorce of ideas from structural conditions is artificial; in fact, it may often be ideas about material circumstances that are most influential in reproductive decision making'. Diffusion effects can actually reinforce the effects of structural changes, and they can explain time lags between economic shifts and the fertility response to the new conditions (Montgomery and Casterline, 1993; Bongaarts and Watkins, 1996; Cleland, 2001).

In summary, whereas the debate around fertility transition has long been dominated by two rival sets of explanations, there are strong arguments that hold that a dichotomisation between structural and cultural/diffusionist hypotheses is too simplistic and counterproductive. At this point, it can be stated that (i) *cultural and structural changes are complementary, rather than rival explanations of fertility decline*; and (ii) diffusion is likely to be an important dimension of fertility transition, but it is not a simple by-product of cultural change; *diffusion is something else entirely that can operate under either structural or cultural shifts.*

A later body of work dedicated more attention and energy to the study of diffusion effects. These studies allow one to go beyond the debate 'culture *versus* economics' and offer a proper framework to analyse how diffusion effects operate in fertility transition.

1.2. Diffusion effects in fertility change

Whereas the European Fertility Project findings suggested that diffusion was an important component of fertility transition, the evidence was largely indirect. The arguments supporting the diffusion hypothesis were based on the simple observation of maps, displaying the gradual evolution of fertility at the province level every ten years. 'Diffusion' was taken as a synonym of 'space-time spread' of fertility decline (Montgomery and Casterline, 1993). The early interpretations lacked, however, a clear definition of what diffusion effects were and how they operated (Pollak and Watkins, 1993).

Diffusion theories have been present in the social sciences for a long time (Casterline, 2001). Empirical studies in sociology had developed conceptual frameworks and formal models since the 1960s in order to study the diffusion of innovative behaviour (Rogers, 1962). Nonetheless, it was not until the 1990s that proper diffusion frameworks were integrated into fertility studies, mainly by three complementary approaches. These approaches offer a solid basis to the study of diffusion at the macro as well as at the micro level. Their concepts and tools are used in most empirical studies of diffusion in demography.

This section describes the three main diffusion frameworks used in fertility studies. After that, based on the common foundations of these frameworks, I discuss some important questions in respect to diffusion: *what diffusion is*, *what is diffused*, *how* *it is diffused*, the *role of family and gender systems on diffusion*, the *causal power of diffusion on fertility* and its implications in terms of *convergence of fertility behaviour*.

1.2.1. Diffusion in fertility studies: three complementary approaches

From local to national communities

Watkins and collaborators highlighted the role of social interaction in the process of fertility transition. In a first article Watkins (1990) reviewed the European Fertility Project data at the province level in Europe. In a second article Bongaarts and Watkins (1996) analysed fertility transition in developing countries using economic and demographic data at the country level. Even though their evidence is mostly indirect and based on highly aggregated data, they developed a clear conceptual and theoretical framework to explain the spatial-temporal patterns of fertility decline.

The premise of these studies is that one's behaviour is influenced by the people with whom he or she interacts. 'Put simply, I assume that in the end it is individuals who act in the privacy of their bedrooms; I suppose, however, that even when the couple is literally alone in the bedroom, the echoes of conversations with kin and neighbors influence their actions' (Watkins, 1990, p. 242). These kin and neighbours 'reward the well-behaved and disapprove of those who stray and they also provide models for behavior and conversational opportunities to consider alternatives' (Watkins, 1990, p. 251).

According to the authors, most of the social interaction in the past was confined to local communities. Conversational opportunities were limited because of the existence of local dialects, low spatial mobility and economic activities organised at the community level. The local nature of social interactions has most probably inhibited the onset of fertility decline, acting as a moral control on individuals' choices to limit their fertility. As countries became politically, culturally and economically organised, not only did the costs and benefits of having children changed, but the 'channels of social interaction' began to expand. Socioeconomic development favoured labour migration, and the creation of transport and communication infrastructure fostered the flow of people and information within the countries. Moreover, the unification of the national language and the creation of national education systems helped to break communication barriers and created a sense of national identity. New opportunities for social interaction were created, well beyond the local level, as the channels of social interaction shifted from local to national communities. As a consequence, people could have more access to new examples and information about birth control, and they were less influenced by local social control.

Bongaarts and Watkins (1996) recognise the importance of socioeconomic development to the onset of fertility decline. However, they argue that social interaction is a fundamental component of the transition process. The timing, the pace and the geography of fertility decline will be shaped by the way channels of interaction develop and how they connect different communities.

The RWA model

The Ready-Willing-Able (RWA) model, conceived by Lesthaeghe and collaborators (Lesthaeghe and Vanderhoeft, 1999, 2001; Lesthaeghe and Neels, 2002), offers a general framework to assess the spatial-temporal patterns of innovative behaviours. The model is derived from Coale's three preconditions for fertility transition (see section 1.1), but it applies to any social change. It states that for a new behaviour to be adopted (i) it must be advantageous for the individuals, i.e. the benefits of adoption have to outweigh the costs (*ready*); (ii) it must be morally and culturally acceptable (*willing*); and (iii) individuals must have sufficient knowledge and means to adopt it (*able*). Innovation will not occur until the three preconditions are met jointly. This means that the spread of the innovative behaviour in space and time will be defined by the last of the three preconditions to be met – the 'bottleneck condition'.

Each one of the three preconditions is linked to a diffusion process. Changes related to *ready*, *willing* and *able* start at a 'locus of initial innovation' and diffuses through social interaction until it meets barriers, such as cultural boundaries, linguistic borders, etc. These barriers are not necessarily the same for each precondition (for example, a cultural barrier may not be an economic one). Eventually the diffusion processes will produce a particular geographic pattern of behavioural change, which mirrors the diffusion pattern of the bottleneck condition.

The RWA framework has been used in the literature to analyse the spatial patterns of two major phases of demographic innovation. The first phase is referred to as the First Demographic Transition, which corresponds to the historical fertility decline and the generalisation of nuptiality at younger ages. The second phase, known as Second Demographic Transition, gathers the behavioural changes from the 1960s on. This includes the rise in cohabitation, divorce and fertility postponement[5].

Lesthaeghe's studies on Belgium, France, Switzerland (Lesthaeghe and Neels, 2002) and Spain (Lesthaeghe and Lopez-Gay, 2013) used a series of demographic, cultural and socioeconomic indicators at the aggregate level. The results show that *willing* was the last precondition to be met in both the First and the Second Demographic Transitions in these countries. The waves of secularisation and individuation that made innovative demographic behaviours morally acceptable shaped the geography of demographic change in the two transitions. Furthermore, an interesting outcome of these studies is that the spatial patterns of change were very similar in the two transitions (except for Spain). This suggests that the channels of social interaction and the barriers to diffusion of new values and attitudes towards family behaviour remained

[5] For examples of the use of the RWA model to the study of the Second Demographic Transition see Sobotka (2008) and Valkonen et al. (2008).

stable throughout time. In Lesthaeghe's terms, there was a permanence of 'regional sub-cultures' in space and time.

Social dynamics

Whereas the two first approaches are concerned with the macro, spatial-temporal patterns of diffusion, the third approach assesses what happens underneath these patterns. It focuses on the individual mechanisms at play in the spread of innovative fertility behaviour and contraception use – or more simply, the *social dynamics* of diffusion processes. In a series of contributions, Casterline, Kohler, Montgomery and Rosero-Bixby developed micro decision-making models allowing to produce more direct evidence of diffusion effects (Montgomery and Casterline, 1993; Rosero-Bixby and Casterline, 1993, 1994; Montgomery and Casterline, 1996; Kohler, 1997; Montgomery and Chung, 1999; Kohler, 2000).

The basic assumption of social dynamics models is that changes in attitudes and behaviours by some individuals can increase the likelihood that other individuals will adopt the same attitudes and behaviours (Casterline, 2001). The very dynamics of the diffusion process influences individuals to make decisions that differ from those they would have made in isolation from the process. These models are often called 'endogenous feedback models' (Erbring and Young, 1979) or 'contagion models' (Rosero-Bixby and Casterline, 1993), as changes in behaviour further foster change (Montgomery and Casterline, 1993).

A fundamental distinction between social dynamics and structural models lies in their views of individual rationality (Palloni, 2001). Structural models are often based on the postulate that information is perfect and each individual has full knowledge of prices and risks involved in reproductive choices. In these models fertility decline occurs when, under new economic circumstances, individuals re-evaluate their costs and benefits of having children and decide to limit their fertility. The fertility level of a population is simply the aggregate of isolated individual decisions. Social dynamic models, on the other hand, admit that information is not available for everyone. Rather, decisions are made under a high level of uncertainty (Montgomery and Casterline, 1996). In this context, individuals try to gather information from the sources available to them in order to minimise risks and to build the foundations of their decisions. Other individual's thoughts, attitudes and behaviours are an important source of information. The fertility of a population is hence the outcome of 'complex social interactions' (Rosero-Bixby and Casterline, 1993, p. 165).

A general specification of social dynamic models can be represented as follows (Casterline, 2001):

$$Y_{it} = \beta X_{it} + \alpha \sum Y_{jt-1} W_j + \varepsilon_{it} \tag{1.1}$$

This simple model represents the adoption of a given behaviour Y by individual i at time

t. This adoption depends on a set of structural and cultural characteristics X, which can be interpreted as the social and economic costs and benefits of adopting Y. But the adoption of Y by individual i also depends on the behaviour of other individuals j at time $t-1$. Each significant individual j is weighted (W) according to their relevance to individual i. This represents the individual's network. The coefficient α denotes the extent to which the past behaviour of others affect an individual's likelihood of adopting the same behaviour in the present: it captures thus the contagion or diffusion effect.

In sum, the essence of social dynamic models is that fertility decisions are not made by isolated individuals. Rather, the process of fertility change has its own contagion dynamics, in which individuals influence the behaviour of other individuals and the aggregate fertility outcome is the result of social interactions.

1.2.2. Key concepts in diffusion studies (What is diffusion?)

The three models described above draw the theoretical basis for the study of diffusion effects in fertility change. They are based on a common conceptual reference and complement each other. Watkins' approach describes how social interaction can influence the onset and the speed of fertility transitions. The RWA model offers a comprehensive framework to the study of the spread of new behaviours in space and time. Social dynamics models describe how diffusion operates at the individual level and offer tools to estimate diffusion effects in the process of fertility change.

The following key concepts can be extracted from these models:

- *Diffusion* is the process through which ideas and attitudes are disseminated among individuals by means of social interaction – ideas and attitudes that might (or might not) be translated into the adoption of new behaviours.
- *Diffusion effects* refer to a contagion dynamics in which the adoption of a given behaviour by some individuals alters the likelihood that other individuals will adopt the same behaviour. Change stimulates further change.
- From a macro perspective, diffusion produces particular *spatial-temporal patterns*. If social interactions were random, a new behaviour would propagate from a locus of innovation towards all directions and at a constant speed. However, behavioural changes are influenced by the way social interactions are organised: the speed and the geography of propagation is thus shaped by the way individuals and communities are connected.

1.2.3. Diffusion factors (What is diffused?)

A basic question in respect to diffusion concerns *what* is diffused among individuals. Diffusion concerns the flow of ideas and attitudes that can be related to economic, cultural or technical factors:

- When there is uncertainty about costs and benefits of adopting a behaviour individuals can gather relevant information by observing or interacting with other individuals. In fact, the implication of economic changes can be rather abstract. Often, individuals do not know the relevant costs of childrearing and the benefits the children might bring in terms of labour, nor do they know the appropriate weights to ascribe to these costs and benefits (Bongaarts and Watkins, 1996, p. 658). Diffusion mechanisms can render economic changes intelligible to individuals 'in the form of stories, examples, and metaphors' (Montgomery and Casterline, 1996, p. 160).
- Diffusion can involve social norms about a given behaviour. Group norms exert an influence on individuals to adopt (or resist the adoption of) a behaviour (Montgomery and Casterline, 1996). For instance, if contraception is unacceptable in a group or community diffusion can prevent individuals to limit their number of births (Watkins and Danzi, 1995; Bongaarts and Watkins, 1996). On the other hand, contraception can become morally acceptable with the diffusion of new values about religion and individuality (Lesthaeghe and Neels, 2002).
- Diffusion might also occur when individuals lack information about behavioural choices (Montgomery and Casterline, 1996), such as contraceptive techniques.

It is not simple to empirically disentangle the factors being diffused. For example, the model described by equation 1.1 does not allow to distinguish whether diffusion concerns ideas about economic, cultural or technical factors; it only captures the contagion effect of the diffusion process.

It is interesting to note that the innovative aspect of ideas and attitudes is not crucial in diffusion models (Casterline, 2001). Diffusion can concern an existing behaviour that becomes more prevalent as other conditions change. It does not necessarily imply the advent of a new idea or behaviour that was previously non-existent.

Moreover, it is clear from this description that diffusion effects can either instigate or inhibit the adoption of a given behaviour.

1.2.4. Diffusion mechanisms (How is it diffused?)

Another basic question concerns the mechanisms through which ideas are disseminated among individuals. The literature identifies a multitude of these mechanisms (Casterline, 2001; Bernardi, 2003). They can nonetheless be condensed into two broader types of 'social effects': social learning and social influence (Montgomery and Casterline, 1996).

Social learning is a process that produces 'additional pieces of information essential to the decision-making process' (Bernardi, 2003, p. 535). In other words, social learning allows individuals to gain knowledge that helps clarify the costs and benefits of adopting a new behaviour (Montgomery and Chung, 1999).

Social learning can take place interpersonally, when individuals obtain information by interacting with relatives, peers, groups or others. There is in fact empirical evidence that women did and do talk about fertility strategies (Watkins and Danzi, 1995; Cleland, 2001; Bernardi, 2003). But social learning does not necessarily involve communication; it can also take place impersonally. The simple exposure to the experience of others can generate concrete evidence on the benefits of adopting a certain behaviour, or the difficulties this behaviour might imply (Bernardi, 2003). This process is called 'demonstration effect' (Rosero-Bixby and Casterline, 1994). Another type of impersonal social learning can come from 'external sources' such as the mass media, marketing efforts and institutional campaigns, that provide concrete information and examples about the adoption of a given behaviour (Rosero-Bixby and Casterline, 1993).

Social influence is 'the effect of individuals' perception of the view of others on their own behavior' (Montgomery and Casterline, 1996, p.659). It is commonly assumed that individuals seek conformity to the groups they belong to (Bongaarts and Watkins, 1996; Montgomery and Casterline, 1996). If groups impose sanctions or rewards to the adoption of a behaviour then individuals might consider these sanctions and rewards as part of their decision-making, in order to avoid conflict. Social influence is produced when a group's view alters the costs and benefits of an individual's behaviour adoptions.

Social influence on fertility choices can be exert by parents, peer pressure, or hierarchical authorities and institutions (Montgomery and Casterline, 1996; Bernardi, 2003). For example, as mentioned earlier, fertility control was considered morally unacceptable for a long time in European societies. The Catholic Church exerted social influence directly, as it clearly condemned contraception in texts and celebrations (Alter and Gutmann, 2005). Indirectly, religious beliefs influenced behaviour through moral control within communities. For a long time these two sources of social influence made the 'social cost' of contraception too high, even if individuals had objective reasons for controlling their fertility (Bongaarts and Watkins, 1996; Lesthaeghe and Neels, 2002).

Although social learning and social influence differ in nature, they have similar effects (Montgomery and Casterline, 1996). For instance, in a model such as in equation 1.1, the diffusion effect α could be the result of either social learning or social influence. The only case that the equation does not take into account is the social learning from external sources (e.g. mass media) and therefore not from other individuals (Rosero-Bixby and Casterline, 1993, 1994). Kohler et al. (2001) argued that the respective contribution of social learning and social influence can depend on the specific context and the characteristics of social networks, such as their density. Moreover, empirical studies using qualitative methods have shown that diffusion mechanisms are complex and often intertwined. Whereas they are easily distinguished theoretically or in diffusion narratives, it is much less simple to disentangle them empirically (Bernardi, 2003; Matthys, 2013).

The way diffusion mechanisms operate depends on how individuals are interconnected. Diffusion of new ideas frequently occur not through homogeneous relations, but through 'weak ties' (Granovetter, 1973). Homogeneous networks can inhibit diffusion in two ways: they create less opportunities for new ideas to appear (Van Bavel, 2004a) and they exert social influence that prevents new behaviours from being adopted (Bongaarts and Watkins, 1996). New ideas can flow more freely when observing or interacting with people from different places or social classes. As a consequence of this, the structure of social relations determines the speed in which new behaviour diffuses. At the macro level the way communities are connected determines the speed, as well as the spatial pattern through which behaviours are diffused.

1.2.5. Diffusion and gender and family systems

Diffusion processes in a given society are likely to be affected by the prevailing gender and family systems, i.e. the organisation of rights and obligations of kin and male-female relationships (Mason, 2001).

In the context of European and North American fertility transitions during the late nineteenth and early twentieth centuries, patriarchy was a defining trait of gender and family systems (Folbre, 1983; Bras, 2014). Common beliefs and social norms, as well as formal rules, were largely defined by older male members of the society, who controlled virtually all the spheres of common life: the church, politics, the labour market and the household. Parents had control over the material resources of their unmarried children; even after marriage youngsters were usually expected to support their parents in their old life (Bras, 2014). Likewise, husbands had full power over the household, sometimes even stipulated by law, whereas wives were expected to be obedient (Bras, 2014).

Birth control methods available at the time – mainly *coitus interruptus*, the condom and abstinence – were also controlled by men (Mason, 2001). Women's bargaining power in respect to family planning was limited (Folbre, 1983; McDonald, 2000; Mason, 2001). Because of the economical interest of parents towards their youngsters, patriarchal gender and family systems were intrinsically pro-natal (Folbre, 1983). Patriarchy would have therefore worked as a social influence force, preventing the adoption of birth control (Bras, 2014).

Patriarchy began being undermined as a consequence of the rise of wage labour during industrialisation (Bras, 2014; McDonald, 2000). Youngsters became less and less dependent on their fathers' material and moral control, and thus more autonomous in their decision-making in respect to marriage and family planning (Folbre, 1983). In this context, patriarchal social influence decreased, and opportunities for social learning of the benefits of family limitation and its moral acceptability increased. Individuals' social networks in the industrial/urban labour market were expanded and they were more exposed to new ideas and values towards fertility. Furthermore, women had more regular access to education and to work. They were increasingly familiarised to the world outside the household and had more control over material resources (Mason, 2001). They were also exposed to social learning and their bargaining power inside the household became stronger (Bras, 2014). Women's wishes were more likely to be deferred by their husband in a less patriarchal context, especially if they were educated (McDonald, 2000).

In the context of contemporary fertility transitions, innovative birth control methods (such as the pill and sterilisation) gave women more freedom over their reproductive choices. It is not surprising that family planning programmes in the twentieth century were directed specifically to women (McDonald, 2000). Women's social networks became a central interest in fertility studies.

Despite the clear influence of family and gender systems on diffusion mechanisms, only a few studies have addressed these matters[6]. Most studies about diffusion in the historical transition overlook gender relations in reproductive choices, limiting the discussion to individuals' or couples' fertility choices (Watkins, 1990; Van Bavel, 2004a). On the other hand, works on contemporary transitions focus on women's decisions and women's social networks (Valente et al., 1997; Montgomery and Chung, 1999; Kohler et al., 2001) without discussing gender interplays on reproduction.

1.2.6. Diffusion and causality

Hitherto, diffusion has been mentioned as a fundamental *dimension* or *component* of fertility change. However, an important question that still needs to be addressed concerns the role of diffusion in terms of causality. Can diffusion be considered a *causal factor* of fertility change?

Diffusion frameworks are multilevel by definition, as they involve aggregate variables – such as macro structural and cultural factors – and their effects on individual behaviour (Montgomery and Casterline, 1996). As noted by Kohler (2000), diffusion works at an intermediate level between macro and micro: social interactions can be seen as a way through which the abstract forces of macro factors are filtered down and shape individual fertility. Hence, diffusion can explain why changes in individual fertility behaviour are often not synchronised with variations in the macro determinants (Rossier and Bernardi, 2009).

Three situations can illustrate how diffusion may either accelerate or delay the effect of macro changes on fertility behaviour.

- Some studies have shown that there is often a lag between economic development and fertility response (Montgomery and Casterline, 1996). In fact, assuming that information is not perfect, individuals do not immediately know the concrete implications of the new economic circumstances (Bongaarts and Watkins, 1996). It takes time for individuals to create a new perception of the costs and benefits of childrearing – which they do by social interaction, observation, etc. The delay between economic change and fertility response is the time it takes for new reproductive strategies to be diffused.
- A lag between economic development and fertility change may also be observed if

[6] See for example Bras (2014).

social influence prevents fertility change. Even if individuals would have concrete reasons to limit their fertility, moral control could be so strong that it would effectively inhibit contraception (Bongaarts and Watkins, 1996). Fertility decline, in this case, will only take place when new values towards contraception begin to spread (Lesthaeghe and Neels, 2002).

- Diffusion can not only delay, but also produce bursts of fertility change (Montgomery and Casterline, 1996). Bongaarts and Watkins (1996) noted that once fertility decline starts somewhere in response to economic development, diffusion can stimulate fertility changes elsewhere, even in places where macro conditions are not the same. Diffusion, in this case, anticipates the onset of fertility transition in places where economic development lays behind.

These scenarios make clear that *diffusion can affect the onset of fertility change.*

Furthermore, as pointed out before, the structure of social relations and the type of social effects dictates how fast a new behaviour will spread. The more individuals, communities and regions are connected, the faster a new behaviour will be diffused (Bongaarts and Watkins, 1996). As a consequence, *diffusion can have an impact on the speed of fertility transition.*

Diffusion therefore has its own independent dynamics within the fertility transition process (Casterline, 2001). However, diffusion cannot act alone. It necessarily carries ideas about economic, cultural or technical factors. As noted by (Rosero-Bixby and Casterline, 1994, p. 459), diffusion effects 'are wrapped up in the process of fertility change; they cannot be extricated theoretically or empirically from the process itself'. Diffusion can be considered as an endogenous dynamics within the transition. The nature of its effect is thus different from exogenous factors such as structural and cultural change.

In sum, diffusion cannot be considered as a direct determinant of fertility itself in the same way as structural and cultural variables. Nonetheless, *diffusion may be a causal factor of the timing and the pace of fertility change* (Rosero-Bixby and Casterline, 1994; Casterline, 2001).

1.2.7. Diffusion and convergence

A final point that needs to be raised is the outcome of diffusion processes in terms of convergence, i.e. whether diffusion implies that all individuals under similar socioeconomic and cultural circumstances will eventually adopt the same behaviours everywhere.

Although fertility decline affected practically every population in the world, there is still persistent diversity in reproductive behaviour and fertility choices within societies and across space (Watkins, 1990; Kuijsten, 1996; Billari and Wilson, 2001; Lesthaeghe and Neels, 2002). This diversity is not incompatible with diffusion theories. In fact, there are several reasons why diffusion processes do not necessarily result in convergence.

Within societies communication barriers can prevent ideas and attitudes from spreading (e.g. among different social classes). In addition, Kohler (1997) has shown that, even if there is communication, the exchange of information about fertility strategies among women can be limited. This may prevent the homogenisation of behaviour and create different fertility patterns in the population.

Diffusion does not imply spatial convergence either. Not only do political and linguistic boundaries hinder diffusion (Watkins, 1990; Decroly and Grasland, 1993), but local particularities can also determine the specific shapes of a general fertility trend (Costa et al., 2011). As mentioned above, Lesthaeghe and Neels (2002) showed the permanence of 'regional subcultures' across time that can influence the spatial-temporal pattens of diffusion. Using a similar notion, Szreter (1996) draws on the concept of 'communication communities', which are geographical localities with a specific history of economic activities and social organisation. These communities consist of a social network of people sharing a common dialect, manners and values about family life[7]. The particularities of communication communities, he argues, can shape different fertility transitions (Szreter, 2011). The idea is that major demographic trends, such as fertility decline, may be filtered and adapted by each community according to its own singularities. As pointed out by Reher (1998, p. 221), 'No matter how nearly universal the factors of modernization may be, once they enter into contact with different historical, cultural, geographical, or social realities, the end result will necessarily be different in each context'.

1.3. Empirical studies on diffusion in fertility change

The concepts and tools described in section 1.2 have been used in empirical studies on diffusion processes in the fertility transition and in the adoption of contraception.

Data availability is a major constraint for these studies for two main reasons. Firstly, an appropriate dataset must contain a time-span of some kind in order to capture contagion effects, i.e. how the past behaviour of some individuals (or in a given place) influence the present behaviour of other individuals (in other places). Secondly, data on social networks is rarely available. Unless specific questions are included in surveys this kind of information must be inferred indirectly. Social interaction is often approached by indicators of language, geographic proximity, etc.

The first empirical works on fertility using proper diffusion frameworks focused on 'contemporary' transitions during the second half of the twentieth century. They benefited from new datasets at the aggregate level offering some temporal and spatial detail, as well as from rich individual datasets from surveys. More recently, diffusion effects in 'historical' transitions has gained renewed interest. New historical data made available provide a great level of detail and allow the use of new and more sophisticated methods. The contributions in these two bodies – contemporary and

[7]See also Garret et al. (2001).

historical transitions – are presented below, focusing on the methods used and the general results.

Needless to say, diffusion has been studied in other contexts. For example, Hedström (1994) used contagion models to study the growth and spread of trade unions in Sweden. Very interesting research has more recently been done on the diffusion of new behaviours in the context of the Second Demographic Transition (Nazio and Blossfeld, 2003; Rindfuss et al., 2004). However, for the purpose of this thesis I focus on fertility studies only.

1.3.1. Diffusion in contemporary transitions

Casterline, Montgomery and Rosero-Bixby were the first ones to apply social dynamic models to the context of fertility transitions. In the absence of individual data their first works relied on aggregate panel data offering great spatial and temporal detail for Taiwan (Montgomery and Casterline, 1993) and Costa Rica (Rosero-Bixby and Casterline, 1994). The pooled annual time series consisted of 100 Costa Rican counties (1958–1988) and 361 Taiwanese townships (1961–1981). The mapping of the countries data reveals spatial-temporal patterns suggesting a contagion process, with fertility decline spreading gradually among contiguous areas. In order to confirm that these spatial-temporal patterns really reflect contagion processes they estimate a formal model controlling for socioeconomic characteristics and measuring diffusion effects. In reality, both studies draw on similar models to the one described in equation 1.1. However, instead of individuals, contagion effects are tested on spatial areas. The independent variable is the community's marital fertility level. Covariates include socioeconomic variables and two types of diffusion effects. The first one is represented by a time-lagged term of the past fertility level in the community (within-community diffusion). The second one is a spatial-lagged term, accounting for fertility levels in surrounding communities (across-community diffusion). The results of the econometric regressions suggest that diffusion effects played an important role in the speed of transition in both countries[8].

In a more recent study Schmertmann et al. (2010) propose an interesting method adapted from epidemiology statistics in order to investigate contagion effects in Brazil, using census data on 502 subnational regions between 1960 and 2000. They first note that the geography of transition in Brazil is highly patterned: the maps show a clear space-time clustering of fertility decline among regions. Their aim is to confirm that these patterns are produced by a contagion processes and not by the space-time clustering of other factors, such as cultural change or socioeconomic development. To do so, they combine Knox statistics, which offer a formal test for space-time interaction, with Cox proportional hazard model. Their results suggest that even after controlling

[8]Results for cross-community diffusion are less conclusive for Taiwan, although the authors attribute this to data issues.

for cultural and socioeconomic change there is a substantial amount of the space-time clustering of fertility decline that remains unexplained. This indicates that a real contagion process was at play in the onset of fertility transition in Brazil.

At the micro level, Montgomery and Chung (1999) used the social dynamics framework on individual data from a sample of rural towns in South Korea from 1973. In addition to information on contraception use and socioeconomic factors the dataset offered rich information on women's social networks. This included the content of their conversations about contraception, their acceptance towards different contraceptive methods and more. The results show that interpersonal diffusion has a significant impact on the likelihood to use contraception, net of socioeconomic factors.

Valente et al. (1997) carried out similar research for Cameroon. They relied on an individual dataset from a 1993 survey conducted in Yaoundé, which also contains information on contraceptive use and social networks. Using a series of a multivariate logistic models, they demonstrate that the contraceptive behaviours and perceptions of a woman's network partners are relevant in her own contraceptive behaviour. Of note, diffusion effects were shown to be more relevant in contraceptive choices than the women's individual characteristics.

1.3.2. Diffusion in historical transitions

As mentioned in the first two sections, the early evidence of diffusion in the European transition was largely indirect. Most studies relied on the European Fertility Project data or similar datasets containing indirect indicators at highly aggregated spatial levels. Bocquet-Appel and Jakobi (1996, 1998), for instance, used spatial analysis to examine the spread of fertility control among European provinces and British counties. However, these studies do not control for socioeconomic variables. Even if they describe spatial-temporal patterns of the transition, they do not demonstrate the existence of contagion effects.

Recently, a certain reawakening of diffusion studies can be noticed in historical demography. A few recent studies have used detailed datasets and sophisticated methods in order to analyse the role of diffusion in the European fertility transition.

Goldstein and Klüsener (2014) conducted a spatial analysis of the fertility transition in Prussia using pooled data from population censuses between 1890 and 1910. The panel dataset consisted of a wide range of socioeconomic and cultural indicators at the level of the Prussian *Kreise*, with a total of 407 small districts. They used panel regression models in order to estimate the district's fertility level as a function of structural and cultural variables, as well as of a spatial-lagged term accounting for fertility change in the neighbouring districts. The last term is included to seize contagion effects: it captures the amount of the space-time pattern of fertility change that is not explained by the spatial clustering of the structural and cultural variables. While both cultural and structural factors seem to be relevant in the Prussian fertility decline, contagion effects were found to also play an important role. Moreover, these effects were found to be stronger around urban areas and along important communication and transportation axes (e.g. the Rhine Valley). This suggests that fertility change was faster where there were more opportunities for social interaction. The authors argue that structural factors set off fertility decline first in urban areas, where it ‘made sense’ to control births to face new economic conditions; it then diffused from there to other areas, where economic conditions and motivations were quite different.

A similar study was conducted by Murphy (2015) in the context of the French fertility transition. He also used pooled cross-sectional data in five moments between 1876 and 1896 in order to estimate panel regression models. Although the spatial data, mostly based on official statistics, allowed the construction of a rich indicators set, these were limited to the coarse level of the 87 French *départements*. The dependent variable used in the models was the *départements*’ marital fertility index (I_g, i.e. the same indirect indicator used in the EFP). Covariates included not only a range of cultural, economic and demographic variables, but also a diffusion term. For a given *département* i at time t the diffusion term accounted for the I_g level of each one of the other *départements* j at time $t-1$, weighted by the distance between i and each j. The results of the series of panel models suggest that both cultural and economic variables contributed to fertility decline in France, but diffusion also seems to have played an important role. Even after controlling for structural and cultural factors the fertility level of *départements* was significantly affected by previous fertility levels in their surroundings. The spatial-temporal patterns of fertility change in France seem to have been influenced by diffusion between neighbouring *département*, net of other factors.

Dribe et al. (2013) used a remarkable database from different censuses to assess diffusion processes in Sweden. They benefited from exhaustive micro-level data from the 1890, 1900 and 1910 censuses, which have been recently digitalised, and constructed a multilevel dataset with detailed socioeconomic and demographic information at the individual and at the parish levels. Their aim was to analyse the contribution of social and spatial distance to the adoption of modern fertility behaviour at the onset of the transition. The results from OLS multilevel regressions indicate that during the onset of fertility transition social distance was more restrictive than spatial distance in the adoption of modern fertility. The upper classes started controlling births much earlier than the lower classes. The spread of new reproductive behaviour among the elite was little constrained by geographic distance. On the other hand, diffusion among different classes in the same place was far less intense. The authors hypothesise that upper class members had wider social networks across longer distances. Therefore, they would have better access to information and new values compared to lower classes. In addition, the authors found that a considerable share of upper-class women lived far away from their parishes of birth: these women would be less connected to local networks in their communities and more connected to upper-class networks across long distances. In other words, elite members would have faced less social influence from the local communities, that could otherwise have inhibited the adoption of birth control.

Some works at the micro level have managed to incorporate more precise information on social networks into longitudinal datasets constructed from population registers. Van Bavel (2004a) carried out a detailed study on diffusion effects in the Flemish town of Leuven, Belgium. Based on population registers and vital records, he compiled data on three birth cohorts of working-class couples living in Leuven between 1846 and 1910, during the onset of fertility transition. Apart from individual variables the dataset contained information on neighbourhood characteristics, namely the presence of Francophone and upper-class couples – two groups that had already started their fertility transition at the time. Neighbourhood characteristics are used as a proxy of social networks. In fact, Van Bavel assumes that the neighbourhood was the main place of communication and observation, where social learning could have affected fertility behaviour. The data were used in a logistic model of parity-dependent stopping behaviour, which estimates the impact of social networks on the likelihood of couples to adopt birth control, net of natural and structural characteristics. The results suggest a significative effect of the neighbourhood on fertility control. The presence of Francophone couples living in the same street influenced the odds of non-Francophone couples of adopting stopping behaviour. Assuming that Francophones come from Wallonia, where fertility transition started much earlier, this result gives support to the idea that migrants can bring new values and behaviours from their places of origin. The presence of upper-class couples in the same quarter had a similar effect, suggesting that there was a downwards diffusion of stopping behaviour from the elites to the lower classes. Van Bavel's research points to the importance of 'weak ties' in the process of social learning. The heterogeneous examples available in the neighbourhood – of innovative behaviour of people from other places and other social classes – seems to have provided working-class couples with concrete evidence of the benefits of controlling their fertility.

Matthys (2013) also found evidence of social learning processes in Flanders. She studied the influence of middle- and upper-class employers on the fertility behaviour of rural-born domestic servants in Ghent, Belgium. The qualitative analysis based on different historical sources showed strong evidence of social learning. On the other hand, quantitative analysis results were less conclusive. Based on population registers she constructed a dataset with four birth cohorts of women born between 1830 and 1880 in two rural towns in the outskirts of Ghent. Cox proportional hazard models were used to compare the fertility behaviour of urban servants, rural servants and others. If social learning was to take place then the first group should have displayed earlier fertility control, net of other characteristics. However, this group was not significantly different from the others. Matthys argues that the reason could be that the process of social learning is a long one, and the diffusion of attitudes and values are maybe not immediately translated into new behaviours.

In her work about the fertility transition in the Netherlands, Bras (2014) used information on marriage witnesses in order to approach couples' social networks. Her study builds on the changes in network patterns since the nineteenth century, in which patriarchal relations gradually gave place to horizontal relations composed of lateral kin and age peers. Based on the Historical Sample of the Netherlands (HSN), a sample of individual life courses from vital records and population registers covering the Dutch territory, she linked the reproductive careers of married couples between 1890 and 1940 to their marriage certificates. This way, she gathered detailed socioeconomic and cultural information about couples, and also about the couples' marriage witnesses, such as their origin, age, social class, kinship with the bride and the groom. Cox proportional hazard models and negative binomial regression showed a clear association between the couples' networks and their reproductive behaviour. Couples whose networks were composed of lateral kin and age peers were more prone to adopt birth control, especially if their witnesses came from other social or geographic background. The regressions also showed that the fact that lower classes lagged behind in the transition was not entirely explained by socioeconomic factors, but also by their more patriarchal networks. Her results help elucidate how diffusion mechanisms might have operated during the transition. On the one hand, the decreasing patriarchy meant less social pressure to adopt fertility norms of past generations. On the other hand, the increasing importance of lateral networks encouraged birth control by the process of social learning – all the more if the network was composed of 'weak ties'.

Population registers and censuses are not available in many countries. In the absence of such direct sources, González-Bailón and Murphy (2013) used agent-based simulation in order to reconstruct individual data for France. Their experiment showed that simulations including the effect of social interaction predicted global fertility trends better than simulations without social interaction. This approach opens new perspectives to the study of diffusion in countries where no individual data are available.

1.3.3. Empirical studies: overview

The studies described in this section were carried out in different contexts and using different data and methods. They give solid evidence that diffusion effects did play an important role in fertility transitions. Once fertility decline sets off it initiates a contagion dynamics that is somehow independent of structural and cultural change. Most of the time it accelerates the pace of the transition and creates specific patterns of behavioural change in societies and across space, shaped by the way individuals are interconnected. However, the effect of social influence can hinder the course of transition for some groups of the population and delay the adoption of modern contraception. The studies also show how the composition of individuals' social networks can have a determining impact on reproductive behaviour.

The studies at the macro level focus on the spatial-temporal patterns of fertility change. Their aim is to verify if these patterns are produced by contagion effects and not by the spatial clustering of structural and cultural changes. The main limitation of these studies is that they offer an indirect assessment of diffusion effects. In all of the models 'diffusion' or 'contagion' is approached by the residual spatial clustering that is left after all possible variables are controlled. There is always the risk that the residuals reflect the effect of other variables omitted in the models (Rosero-Bixby and Casterline, 1994; Goldstein and Klüsener, 2014).

Micro studies often have the chance to integrate more direct evidence of diffusion mechanisms. Some surveys carried out in the context of contemporary transitions include direct questions about individuals' networks and perceptions. In the case of historical transitions researchers have found creative ways to approach social interactions indirectly (such as the presence of migrants in the neighbourhood or information on wedding witnesses). However, these studies face a common trade-off between their degree of precision and their power of generalisation. Datasets containing detailed information on social networks are often available at the local level only. Indeed, most of the micro-level studies described above concern a single city or town. Even though they are very rich to elucidate diffusion mechanisms, their findings are highly dependent on their specific contexts and local particularities.

Finally, a general limitation of the quantitative research on diffusion is that, even though they demonstrate that diffusion exists and how it operates, they are less revealing about *what* is being diffused. It is far less simple to distinguish whether the diffusion concerns ideas and attitudes about economic matters, cultural norms or contraceptive knowledge.

1.4. Diffusion in Belgium's fertility transition

The fertility transition in Belgium has been the object of several studies in demography[9], and it offers many possibilities to the analysis of diffusion effects. In spite of its small size, the country is characterised by a great spatial heterogeneity. Its territory is crossed by a linguistic border separating two main linguistic communities – French-speaking Wallonia in the south; and Dutch speaking Flanders in the north – both comprising several dialects and a great diversity of socioeconomic contexts. In addition, Belgium has a long statistical tradition with population registers and vital records, as well as regular censuses.

The most comprehensive study on Belgian fertility transition is undoubtedly Lesthaeghe's monograph from the European Fertility Project (1977). He combined rich historical and sociological research to quantitative analysis based on several indicators at the level of Belgium's 41 arrondissements. His work offers a good view of the determinants

[9]This section focuses on the studies that relate somehow to the subject of diffusion. For an overview of the many historical studies of fertility in Belgium see Neven and Devos (2001), Alter and Gutmann (2005) and Van Bavel (2010).

of the onset of fertility, as well as its spatial and temporal dimensions.

Lesthaeghe (1977, pp 106–109) showed that, although fertility levels were similar in Flanders and Wallonia until circa 1870, fertility first began to decline in a rural Francophone arrondissement near the French border. It was followed by the highly industrialised arrondissements nearby and finally spread to the rest of Wallonia. By 1900, whereas Fertility transition was well underway in Wallonia, its signs were still quiet in Flanders, except for the large urban areas. After 1900, 30 years after the onset in Wallonia, birth control finally spread among Flemish districts.

On the one hand, Flanders and Wallonia had experienced different economic developments since the early nineteenth century: the slow industrialisation in Flanders and the permanence of agriculture and cottage industry was contrasted with the very modern industry in northern Wallonia (Lesthaeghe, 1977, p. 44). On the other hand, socioeconomic differences alone cannot account for the differences in fertility transition in these two regions. As Lesthaeghe shows by a sequence of maps, birth control had spread to rural parts of Wallonia long before it reached much more developed parts of Flanders. In fact, another key determinant of the onset of the transition was found to be secularisation, i.e. the 'gradual shift away from Catholicism' (Lesthaeghe, 1977, p. 6). At the onset of fertility decline secularisation was well stablished in Wallonia, reaching even the more remote rural areas of the Ardennes, whereas in Flanders the adherence to the church remained strong everywhere except for the large urban centres. It was only later that secularisation crossed the linguistic border, taking a similar path as the later spread of fertility decline.

Translating these findings into the RWA model terms (see subsection 1.2.1), Lesthaeghe states that, even though socioeconomic development was an essential component of fertility decline in Belgium (*ready*), secularisation was what shaped the dissemination of birth control. *Willing* was the bottleneck condition that ultimately determined the spread of fertility decline (Lesthaeghe and Neels, 2002; Lesthaeghe and Lopez-Gay, 2013).

Even though these studies indicate that secular ideas were being diffused, they do not bring direct evidence of contagion effects during the transition. Diffusion is an underlying assumption that explains why the spatial-temporal pattens of fertility change mirrors that of secularisation. Apart from this broad picture, what are the other, finer evidences of fertility decline in Belgium?

The clearest evidence of the importance of diffusion is the effect of the linguistic border on reproductive behaviour. In his monograph, Lesthaeghe (1977, pp. 111–114) compared 70 pairs of neighbouring communities situated at opposite sides of the linguistic border. Within each pair, communities were separated by a few kilometres only and had similar socioeconomic circumstances. Yet, by the turn of the century, fertility levels were significantly lower in most of the French-speaking communities. This suggests that in spite of their socioeconomic and geographic proximity, social interaction across the linguistic border was very limited. It is also symptomatic that the number of cross-border marriages was also very low (Lesthaeghe, 1977, p. 227).

Moral control is another example of how diffusion, through the mechanism of social influence, could have affected the course of the transition in Belgium. Micro-level studies in the Charleroi industrial area (Eggerickx et al., 2008) and rural towns in the Liège Province (Neven, 2003) have shown that religious control effectively delayed the onset of fertility transition among certain groups of the population. The adoption of modern fertility was facilitated once this social influence began to fall, as individuals started turning away from religious values.

Eggerickx (2004) carried out a thorough analysis of the fertility transition in the Charleroi industrial area, where fertility decline started very early in the Belgian context. Using different aggregate and individual data sources, he showed that fertility decline in this industrial context was set off by the economic crisis between 1873 and 1892. The new economic conditions imposed by the crisis, he argues, were in contrast with the rising material aspirations, and couples started to limit their number of births as a response to the crisis. These findings are not in contradiction with Lesthaeghe's views: it could be that structural shifts set off fertility control in this industrial area, and was later spread to the rest of Wallonia at the pace of ideational change. In addition, even if Eggerickx does not use a diffusion perspective, his results are consistent with the idea that structural changes initiate the diffusion of new ideas about the costs of childrearing and expectations in terms of education. This could partially explain the lags in birth control that he observed among the different occupational groups, in particular between the forerunning upper classes and the laggard working classes. Such lags were also noted by Van Bavel (2004a) in the town of Leuven and by Matthys (2013) in the city of Ghent (see subsection 1.3.2). All this evidence suggests that a process of social learning was at play, in which the lower classes learned from the elites the benefits of birth control in terms of social mobility, either by observation or by social interaction[10]

Studies at the local level have also suggested the role of migrants in the dissemination of new ideas related to reproduction. As mentioned in subsection 1.3.2, Van Bavel (2004a) demonstrated that Francophones living in Leuven – coming from a background in which transition was way ahead – influenced native couples in the adoption of modern fertility. Moreels and Vandezande (2012) found similar results for the city of Antwerpen. They argued that migrants coming from transitional areas exposed the local population to new attitudes and behaviour related to reproduction. Eggerickx et al. (2008) also noted that migrants in Charleroi were less under the effect of the social control, probably because they were less embedded in the local networks. All these studies confirm the power of 'weak ties' in the dissemination of innovative ideas related to fertility.

A final point worth mentioning is that, although fertility control had spread every-

[10]See also Van Bavel (2010, pp. 452–453).

where in Belgium by 1930, there was no real spatial convergence of reproductive behaviour. Costa et al. (2011) observed persistent regional particularities in terms of age at childbearing, family size and childlessness. This picture is consistent with Szreter's (1996) idea of 'communicating communities' (see subsection 1.2.7): even though fertility transition represents a global trend towards birth control, different areas might experience different transitions and adapt the general fertility trends to its own local particularities.

Chapter 2.

Research design

Based on the theoretical and empirical literature discussed in chapter 1, this chapter builds the research design of the thesis. The first section highlights the lessons taken from the literature review and identifies what has been missing in diffusion studies in general, and in the context of the Belgian fertility transition in particular. In the light of this discussion, section 2.2 presents the aims of the research. The key concepts and assumptions used throughout the thesis are defined in section 2.3. Finally, the last section presents the main research questions and hypotheses that will guide the methodological choices and the quantitative analyses carried out the next chapters.

2.1. Lessons from the literature

The theoretical and empirical evidence presented in chapter 1 holds that both structural and cultural factors are direct determinants of fertility behaviour. Changes in economic circumstances have undoubtedly an impact on couples' fertility choices; in addition, it is clear that such choices are also conditioned by social and moral norms in respect to reproductive behaviour.

However, fertility levels do not always immediately respond to cultural and structural changes. Diffusion processes work as an intermediary between the fertility determinants and their impact on individual behaviour. Diffusion can explain time lags between economic and ideational change and the response in terms of fertility behaviour. From a spatial perspective, changes in economic circumstances in a given place can provoke bursts of fertility change elsewhere via diffusion mechanisms. Once fertility decline sets off in a certain group of the society or in a certain place in space, diffusion effects can start an independent dynamics that dictates the timing, the pace and the geography of the spread of reproductive changes towards other groups or places.

The demographic literature, built on sociological and microeconomic foundations, offers a well grounded conceptual framework for the study of diffusion effects in reproductive behaviour. The theoretical potential of diffusion theory contrasts, however, with the few empirical applications in fertility studies. In fact, such applications are highly dependent on data availability. Ideally, spatial studies on diffusion should use data with great spatial and temporal detail with a relatively long time span in order to cover the fertility transition in a territory. Individual studies must contain some information on individuals' social networks and a time span allowing to test whether individuals' behaviour in the present is influenced by the past behaviour of others in his network. In both cases, structural and cultural variables must be available, as it is necessary to separate diffusion effects from the direct determinants of fertility change. Such detailed datasets are rarely at the disposal of demographers, which explains the small numbers of empirical studies that investigate diffusion effects in fertility transitions. A few works carried out in the 1990s focused on contemporary transitions. They benefited from new datasets produced since the second half of the twentieth century in developing countries. More recently, there is a noticeable reawakening of diffusion studies in the context of historical transitions in Europe, using newly digitised data at fine spatial levels or at the individual (longitudinal) level. It is indeed striking that six out of the seven diffusion studies carried out to date (2015) on the European transition[1] have been published in the last two years.

The rarity of appropriate data imposes another limit on empirical studies: they are frequently confronted with a trade-off between their power of generalisation and their level of detail. On the one hand, spatial works have managed to demonstrate the global effect of contagion processes in fertility transitions of whole territories or countries. However, the evidence they provide of contagion effects is indirect, as it is based on the residual spatial clustering of fertility change after controlling structural and cultural factors. On the other hand, micro-level studies have produced more direct evidence of diffusion effects and elucidated the mechanisms through which diffusion operates. But detailed individual data are often available at the local level only – i.e. a city or town – and, as a consequence, their results are conditioned by local particularities. In addition, cities and towns are studied in isolation from their spatial context. It is not easy, in local studies, to take into account the influences coming from neighbouring places.

To this date, the evidence of diffusion effects in the Belgian fertility transition can be found in the two extremities of this empirical trade-off between general and local.

Lesthaeghe's works (Lesthaeghe, 1977; Lesthaeghe and Neels, 2002; Lesthaeghe and Lopez-Gay, 2013) provide a general interpretation of the determinants of the onset of fertility decline and the spatial-temporal patterns of the transition in Belgium. Yet, his studies are based on highly aggregated indicators calculated every ten years offering a rather 'rough' overview of the spatial and temporal dimensions of the transition. In

[1]Excluding the studies on the spatial-temporal patterns of fertility decline which do not measure diffusion effects directly, such as the ones using the EFP data.

addition, although his studies have hinted that diffusion was at play, they do not use statistical methods that allow to demonstrate the existence of contagion effects.

Studies at the local level carried out in Leuven (Van Bavel, 2004a) and Ghent (Matthys, 2013) are very rich in details. Not only do they provide more direct evidence of diffusion, but they also show the diffusion mechanisms at play during the transition. But these two cities have their own social structures, migration histories, territorial organisation, etc. Both studies highlight how these particularities have played a role in their findings. However illuminating, their results cannot be easily generalised to the whole territory of Belgium.

All the other pieces of evidence of diffusion in Belgium are scattered in studies that do not aim at analysing diffusion: they emerge from indirect results obtained by overall fertility studies.

In summary, no study so far has demonstrated that contagion effects were at play in the Belgian fertility transition as a whole, and how diffusion could have shaped the spatial-temporal patterns of fertility decline across the territory.

A final observation is that most of the empirical studies on the fertility decline in Belgium, as well as in other countries, have focused on the onset of the transition. Most of the research to date covers the late nineteenth and early twentieth centuries. Lesthaeghe's quantitative analyses from his monograph (1977), as well as the individual study by Van Bavel (2004a), concentrate on the beginning of the transition in the turn of the century. The other diffusion studies analysing the cases of Sweden (Dribe et al., 2013) and Prussia (Goldstein and Klüsener, 2014) are also limited to the early phase of the transition, until 1910. In fact, most attention has been given to the early dissemination of birth control from pioneering social groups or spatial areas, whereas little has been said about the laggards in the transition, i.e. the groups and places that resist to the adoption of modern reproductive behaviour and experience late fertility decline.

2.2. Research aims

In the light of the considerations from the literature discussed above, the general aims of this thesis can be formulated as follows.

The *main purpose* of this research is to investigate the role of diffusion in the fertility transition in Belgium. In particular, the analyses aim at verifying to what extent contagion effects determined the timing, the pace and the geography of fertility decline in Belgium.

Three *general principles* will guide the methodological choices in the research:

- The research will favour a global view of the fertility transition, covering the whole Belgian territory.
- The analyses will attempt to integrate individual and spatial approaches in order

to fill the gap between general studies at high aggregate levels and individual studies at local contexts.
- Attention will be given not only to the pioneers of diffusion, but also to the laggard regions and groups that resisted the adoption of modern reproductive behaviour.

2.3. Key concepts and assumptions

I adopt a decision-making approach of fertility inspired by social dynamic models (Montgomery and Casterline, 1996; Casterline, 2001), connected to a spatial perspective based on the works by Watkins and collaborators (Bongaarts and Watkins, 1996; Watkins, 1990). In addition, following the RWA framework (Lesthaeghe and Vanderhoeft, 2001), I presuppose that both cultural and economic factors are preconditions for the adoption of new fertility behaviours.

Individuals are assumed to be rational agents that base their fertility decisions on the calculation of the costs and benefits of having children. These costs and benefits can be related to economic or cultural factors.
- Individuals weigh the economic implications of having children, namely the prices of childrearing and the return that children might represent for the household in terms of labour force and elderly care.
- Individuals also take into account the social implications of adopting a certain reproductive behaviour, especially the costs of deviating from the values and norms imposed by institutions (such as the church) and the community (social and moral control), as well as the personal benefits of attaining a given family size.

However, information is assumed to be imperfect. Individuals do not know all the economic and cultural costs and benefits involved in the adoption of a given fertility behaviour, nor the weights to assign to these costs and benefits. In order to obtain information and reduce the risks and uncertainties of reproductive choices, individuals rely on their social networks. This is done by *social interaction*, which can involve interpersonal communication or observation only.

Diffusion is defined as the flow of ideas among individuals of a social network by social interaction, about economic and cultural costs and benefits of adopting a new behaviour.

Diffusion effect is a process through which the attitudes and behaviours of an individual's network members affect his or her own behavioural decisions. The adoption of innovative reproductive behaviour by a group of individuals might initiate a *contagion* dynamic because it may increase the likelihood of other individuals adopting the same behaviour (change encouraging further change). 'Diffusion effects' and 'contagion effects' are used interchangeably.

Individuals and communities are connected in space according to *channels of social interaction.* These channels depend on the geographic distance between people, but also on the cultural and economic organisation of a territory. This includes the migration flows, the transport infrastructures, the linguistic and dialectal distribution.

Diffusion effects act in space according to the channels of social interaction and their obstacles, such as linguistic borders. In doing so, the diffusion process creates particular *spatial-temporal patterns* of behavioural change. These patterns convey the geography, the timing and the speed in which such change occurs in a given territory.

2.4. Main research questions and hypotheses

The general research question that connects the different analyses of this thesis is the following: *did diffusion effects influenced the timing, the pace and the geography of fertility decline in Belgium?* The main hypothesis is that diffusion effects had its own dynamics, independently of cultural and economic change, and thus shaped the way birth control spread in space and time during the fertility transition process.

The general research question and hypothesis can be declined in more specific ones about the ways diffusion operates:

- *Did the intensity of social interactions and spatial mobility accelerate the diffusion process in Belgium?* Many works have shown that migrants can contribute to the dissemination new ideas and values from their places of origin (Moreels and Vandezande, 2012; Van Bavel, 2004a) and that they are less influenced by the local social control (Eggerickx et al., 2008). Therefore, I expect that the presence of migrants alters the likelihood that native individuals adopt modern fertility behaviour. Furthermore, the more intense the social interactions in a given place, the more opportunities there are for social learning about the benefits and social acceptability of birth control. Therefore, places with intense social interaction should also be more prone to experience an early fertility decline.
- *Why do some regions resist longer to the adoption of modern fertility behaviour?* Communities that are less connected to the rest of the territory in terms of economic activity, spatial mobility and culture (religion, dialects, etc.) are expected to start fertility decline much later than their surrounding areas. These would be the 'regional sub-cultures' (Lesthaeghe and Neels, 2002) or 'communicating communities' (Szreter, 1996) that maintain their particularities across time, and where social influence inhibit the adoption of birth control.
- *Are diffusion effects stronger among the members of the upper educated classes?* Drawing on the findings for Sweden (Dribe et al., 2013), I assume that upper class members are connected to social networks across longer distances. In addition, because the Belgian elite spoke French in Wallonia as well as in Flanders (and not Walloon and Flemish dialects), they would have access to innovative ideas earlier

than the lower classes living in the same place. Educated individuals would thus have more opportunities for social learning, and possibly be less subjected to the delaying forces of social influence.

These are the main, transversal questions and hypotheses that will serve as reference for the methodological choices and the different analyses carried out in this thesis. They will be developed in more detail in the next chapters, taking into consideration the limits imposed by data availability and the possibilities offered by the statistical methods. In the concluding chapter of this manuscript, these points are assessed in respect to the ensemble of results obtained in the different analyses.

Part II.

Data and methods

Chapter 3.

The aggregate dataset

Belgium has a long tradition in data collection, initiated short after its independence in 1830. As soon as 1831, essential demographic figures were collected at an yearly basis in the entire country (Poulain, 1981). The involvement of Adolphe Quetelet, a pioneer in population statistics, gave a significant impulse to the further development of data collection systems in Belgium. In 1841, he founded the world's first state office of statistics – the *Commission centrale de Statistique* –, which produced several regular documents over the years with a broad set of population figures (Poulain, 1981). Also under Quetelet's initiative, Belgium was the first country to establish population registers across its whole territory in 1846 (Gutmann and van de Walle, 1978), alongside the existing vital records. The heritage of these early efforts is a remarkable statistic patrimony, offering consistent, good quality data for the whole Belgian territory and comprising a wide range of demographic and socioeconomic aspects of the population.

Despite the high potential of these historical sources, much of their information has not yet been made available for statistical analysis. A great share of the data is still to be found in manuscripts and books scattered around the country. On the one hand, the compilation of micro data from population registers at the scale of the county is an implausible task, and only punctual studies at the local level have managed to use this source (Oris, 1991; Van Bavel, 2002; Neven, 2003; Eggerickx, 2004; Matthijs and Moreels, 2010). As for spatial data covering the whole country, only highly aggregated levels have been digitised to date in Lesthaeghe's works (Lesthaeghe, 1977; Lesthaeghe and Neels, 2002; Lesthaeghe and Lopez-Gay, 2013).

In order to analyse diffusion effects in the Belgian fertility transition, a new dataset had to be put together, gathering a great amount of data. The construction of this dataset was guided by three criteria, based on the aims of this thesis (see chapter 2).

1. The dataset should include information on demographic, socioeconomic and cultural aspects of the population.
2. Data should cover the whole territory.

3. Data should offer high temporal and spatial detail, and cover as much as possible the time-span of the fertility transition process.

Obviously, these criteria are constrained by the considerable amount of work involved in the digitisation of raw data. Therefore, the construction of the dataset had to take into account the feasibility of data input within the scope of the thesis.

In the light of these criteria, a unique body of data was assembled from different sources to form a detailed dataset for spatial-temporal analysis. This aggregate dataset provides a rage of demographic, economic and cultural indicators at fine geographic scale from 1880 to 1935, offering therefore a high level of spatial and temporal detail throughout a crucial period of the fertility transition process.

The construction of the aggregate dataset was carried out in three phases. In the first phase raw data was gathered from different historical sources. Much of these raw data were available for Belgium's old municipal division, comprising approximately 2,600 municipalities, and thus offering great spatial detail. However, not only did the municipal division changed over the years, but the figures at such a fine level are often too small for the computation of indicators. For this reason, in a second phase some methodological choices had to be made concerning the spatial and temporal aggregation at which the raw data should be used. In a third phase several indicators were computed with the compiled data. The three sections in this chapter respectively describe each one of the three phases.

3.1. Compilation of raw data

Since 1841, Belgium's *Commission centrale de statistique* has collected a great amount of aggregate demographic and socioeconomic data using two complementary tools: censuses and the *Mouvement de la population et de l'état civil* (Poulain, 1981; Bracke and Vanhaute, 2005). Whereas the censuses offer a detailed view of several aspects of the population and the economy approximately every ten years, the *Mouvement* provides annual information on demographic facts based on population registers. These sources were made available in large volumes containing tables of aggregate data, some at the district (*arrondissement*) level, and some the municipal (*commune*) level.

For the purposes of this thesis, the construction of the aggregate dataset relied on the series provided by both the censuses and the *Mouvement*:

- *Mouvement de la population et de l'état civil* from 1880 to 1935;
- Population Censuses of 1880, 1890, 1900, 1910, 1920 and 1930;
- Industrial and Trade Census of 1910.

3.1.1. Preliminary steps for data input

Most of the aggregate data provided by the censuses and by the *Mouvement* had not been digitised before this thesis, at least not at a fine geographic level. For this reason the construction of the aggregate dataset was a considerable task, and one that required much preparation.

A first step was to make an inventory of all available sources, their location, their content and the formats in which they were available (microfilm, paper, digital file, etc.). For each source I first inputted a data sample corresponding to one year of observation. This was done in order to estimate the input time for each data series and also to run preliminary tests to evaluate the data. The choice of the data to be digitised took into account both the input time they required and their relevance for the study. The priority was given to the input of figures offering some spatial and temporal detail, i.e. available at a fine geographic level with consistent frequency covering the period of the Belgian fertility transition (between the end of the nineteenth century until the 1930s).

Whereas some of the data were only available at the level of the 41 districts[1], a considerable share of the data was available for the approximately 2,600 municipalities. Besides the great number of cells to be inputted municipal data imposed extra difficulties for the compilation process. First of all, the number of municipalities fluctuated over the years due to splittings and mergers. What is more, many of the municipalities' names were altered at some point or translated from French to Dutch. Their order of appearance varied from one source to the other and from one year to the other. Municipalities could change from provinces or districts from one year to the next, which also altered the order in which they appeared in the tables. Therefore, in order to facilitate the data input I created a database with all the possible names of each municipality, as well as their first and last date of appearance in the data sources and the districts they ever belonged to.

Prior to the input I prepared digital tables identical to the tables from the original sources, controlling for the ordering of municipalities or districts. These digital tables contained automatic sums identical to the sums provided by the sources, at the bottom of each page and for the total of a district's municipalities. As a result, I could verify the sums at each step of the data input in order to minimise input errors.

3.1.2. Mouvement de la population et de l'état civil

The *Mouvement de la population et de l'état civil* is a key data source for the purposes of this thesis because of its high level of temporal and spatial detail. The series provided by the *Mouvement* contains a broad set of demographic information at the municipal level, year by year since the late nineteenth century, making it a unique data source in Europe.

The *Mouvement* is based on municipalities' population registers, which transcribed all the demographic facts from the vital records – related to births, deaths, marriages and divorces – as well as information on in- and out-migration, allowing therefore for a

[1] The administrative division of Belgium defined 41 districts until 1963, when two additional districts were created.

continuous view of the numbers and structures of a municipality's population (Poulain, 1981, p. 206). These figures were gathered and centralised every year by the *Commission centrale de Statistique* and reported on thematic tables accounting for several demographic features (Poulain, 1981; Bracke, 2010).

The *Mouvement* series are available in annual volumes of manuscripts from 1841 to 1976[2], except for the years during the First and the Second World Wars, for which the manuscripts are incomplete. Figure 3.1 shows an example of a page from the 1889 manuscript. The information reported in the volumes were little altered over the years. The period between 1886 and 1952 is particularly stable, with consistent series of the same tables, year after year[3].

The *Mouvement* is therefore a very rich source of demographic data. It offers a continuous follow-up of the demographic evolution in Belgium at a very detailed geographic level over a long period. However, in contrast with the censuses, data from the *Mouvement* remain largely underused so far (Preneel, 2010). This is mainly due to the considerable task involved in the digitisation of the large amount of data for the numerous municipalities (Bracke and Vanhaute, 2005). In addition, the hand-written figures in the *Mouvement* and the age of the volumes do not allow (to date) the use of optical character recognition (OCR) technology. All the data has to be inputted manually.

Basic demographic figures reported in the *Mouvement* had been digitised prior to this thesis (Poulain, 1981). These annual figures include the **number of births, deaths, in-migration, out-migration and total population, by sex**, for all the Belgian municipalities from 1880 to 1976. From this digital database I selected municipal annual information from 1880 to 1935.

Population figures in the *Mouvement* are often biased due to the unreliable registration of migrations. In particular, out-migrations are poorly registered, leading to an overestimation of the population. Every ten years the results from the population censuses were used to adjust the total population of municipalities in the *Mouvement* (Poulain, 1981). Fortunately, biased population numbers between census years can be easily corrected by redistributing the difference between the estimates from the *Mouvement* and the censuses over the inter-census period (Eggerickx, 2004). The correction was done for the total population of each municipality for the selected years.

Apart from the basic demographic figures, specific information about fertility, marriage and infant mortality was inputted for this thesis.

[2]After 1976 the tables were simplified and published in digital format (Poulain, 1981). All the manuscripts are available at the *Archives générales du Royaume/Algemeen Rijksarchief* in Brussels. Most of them were also kept in microfilms at the Centre for Demographic Research at the Université catholique de Louvain.

[3]For detailed information about the data contained in the *Mouvement* see Poulain (1981), Bracke and Vanhaute (2005) and Preneel (2010).

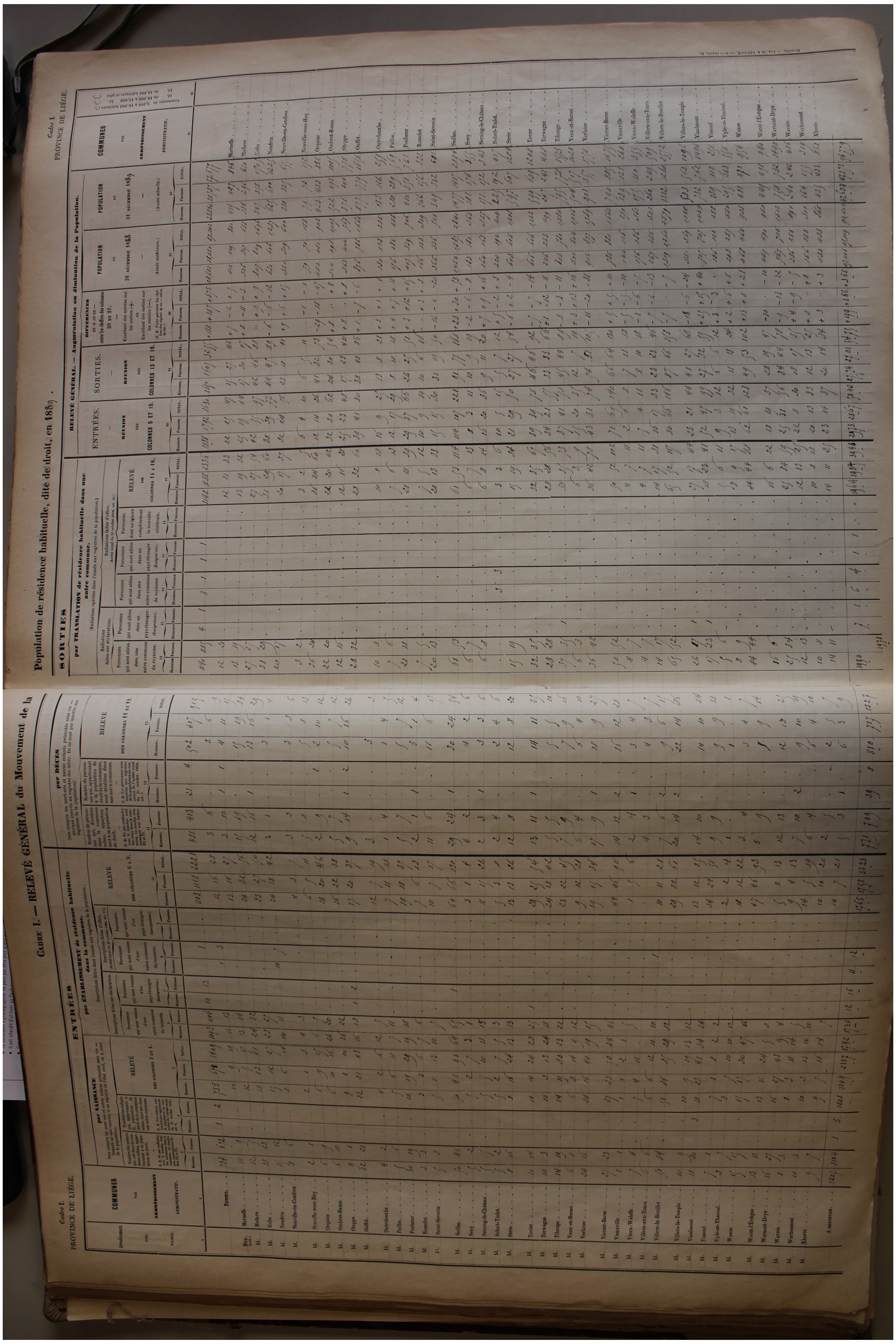


Figure 3.1.: Example of a page from table I of the *Mouvement de la population et de l'état civil* (manuscript from 1889)

The number of **legitimate births** is available in the *Mouvement* series since 1886. This information is essential for our purposes. It is used to compute marital fertility indicators, which will be the main variable allowing to investigate fertility change. In order to obtain as much spatial and temporal precision as possible for fertility, these data were inputted year by year, from 1886 to 1935 (except for the years of the First World War, for which there were no data available).

Specific data on marriages were collected for the calculation of a proxy for secularisation (section 3.3). The computation of this indicator needed the **number of marriages in March**, and the **total number of marriages** over the year. The data were digitised by five-year period in order to avoid random fluctuations due to small numbers: 1886–1890, 1896–1900, 1906–1910, 1919–1923[4] and 1926–1930.

The number of marriages by age category of spouses was digitised for the years 1886 and 1913. The initial idea was to use this information to analyse nuptiality schedule, but tests with these data have indicated little interest for the final analyses. Still, these data were used to discuss the methodological choices in respect to the level of analysis of the aggregate dataset (section 3.3).

Finally, the *Mouvement* series was used to compile the **number of deaths before age one** among children born alive, that serves to compute infant mortality rates. The input of these figures at the municipal level is particularly time-consuming. In fact, before the 1910s the tables reporting deaths by age contained too much detail[5]. For this reason, infant mortality figures were inputted at the district level for the following periods: 1889–1901, 1909–1911, 1919–1921 and 1929–1931. In addition, data at the municipal level were compiled for the 1909–1911 period in order to measure the extent of the statistical precision lost by using districts in stead of municipalities. The evaluation tests are discussed in section 3.2.

3.1.3. Population Censuses

The first Population Census in Belgium was carried out in 1846, producing the first figures available at the municipal level (Poulain, 1981). Population Censuses were organised regularly within ten-year intervals – from 1846 to 1876, from 1880 to 1930, in 1947, and from 1961 to 2001. For the construction of the aggregate dataset I used six editions of the Population Censuses: 1880, 1890, 1900, 1910, 1920 and 1930. These editions cover most of the period of the Belgian fertility decline, except for its early onset, and they correspond to the time-span of the data compiled from the *Mouvement*.

[4]Because the *Mouvement* series were broken during the First World War the five-year period corresponding to the 1910s was moved forward.

[5]In order to obtain the number of deaths before age one from the manuscripts until the 1910s, it would be necessary to sum 80 columns for each municipality: twenty age categories, by sex and by child status (legitimate/illegitimate). For each year of observation, this means the input of approximately (80 columns $\times$ 2,600 municipalities) 208,000 cells.

Similarly to the *Mouvement*, census results are presented in tables of aggregate data, some at the municipal level and some at the district level only. Even though these tables are available in printed books the tests with OCR programmes showed many problems in the recognition of the old characters and layout of the tables. Therefore, all the data were inputted manually. Figure 3.2 shows an example of a page from the 1910 Census.

The content of the censuses varied over the years (Bracke and Vanhaute, 2005). The period between 1890 and 1910 offers consistent data series, with many identical tables at the municipal level over the different editions. On the other hand, the 1920 and 1930 censuses are less rich in detail: many tables are limited to the district level (Poulain, 1981).

The choice of the census content to be inputted followed the above-stated criteria for the data collection. I selected the most relevant data for the study that could be used to compute demographic, socioeconomic and cultural indicators. Priority was given to the data series available in different census years, allowing to produce consistent time series. Whenever available, information at the municipality was favoured over the district level.

The following data series were compiled at the municipal level:

- Number of **native inhabitants** living in the municipality (1880–1930);
- Number of **literate inhabitants** (1880–1930);
- Number of inhabitants by **language spoken** – French only, Flemish only, German only, French and Flemish, French and German, French, Flemish and German – (1880–1910);
- Number of **ever-married women** (1880–1910).

The censuses of 1920 and 1930 did not provide municipal information on the language spoken and ever-married women; these data were thus inputted at the district level for those years.

Age structures are another key information extracted from the censuses, that serves to compute age-standardised indicators. These data are available for districts, as well as for the most important cities within each district, from 1880 to 1920. I compiled the **number of inhabitants by sex and age**, as well as the **number of married women by age**, for districts and cities.

Finally, censuses between 1890 and 1920 provided much information on the occupational structure of districts' populations. Unfortunately, professional sectors were altered from one census to the other and it is impossible to produce coherent data series for specific occupational branches throughout the whole period (Lesthaeghe, 1977). For this reason occupational data from the censuses were grouped in broader categories, forming coherent district-level series from 1890 to 1920 on the following numbers:

- **workers in the industry (blue-collar and white-collar, by sex)**;
- **workers in agriculture (blue-collar and white-collar, by sex)**;
- **workers in trade (blue-collar and white-collar, by sex)**.

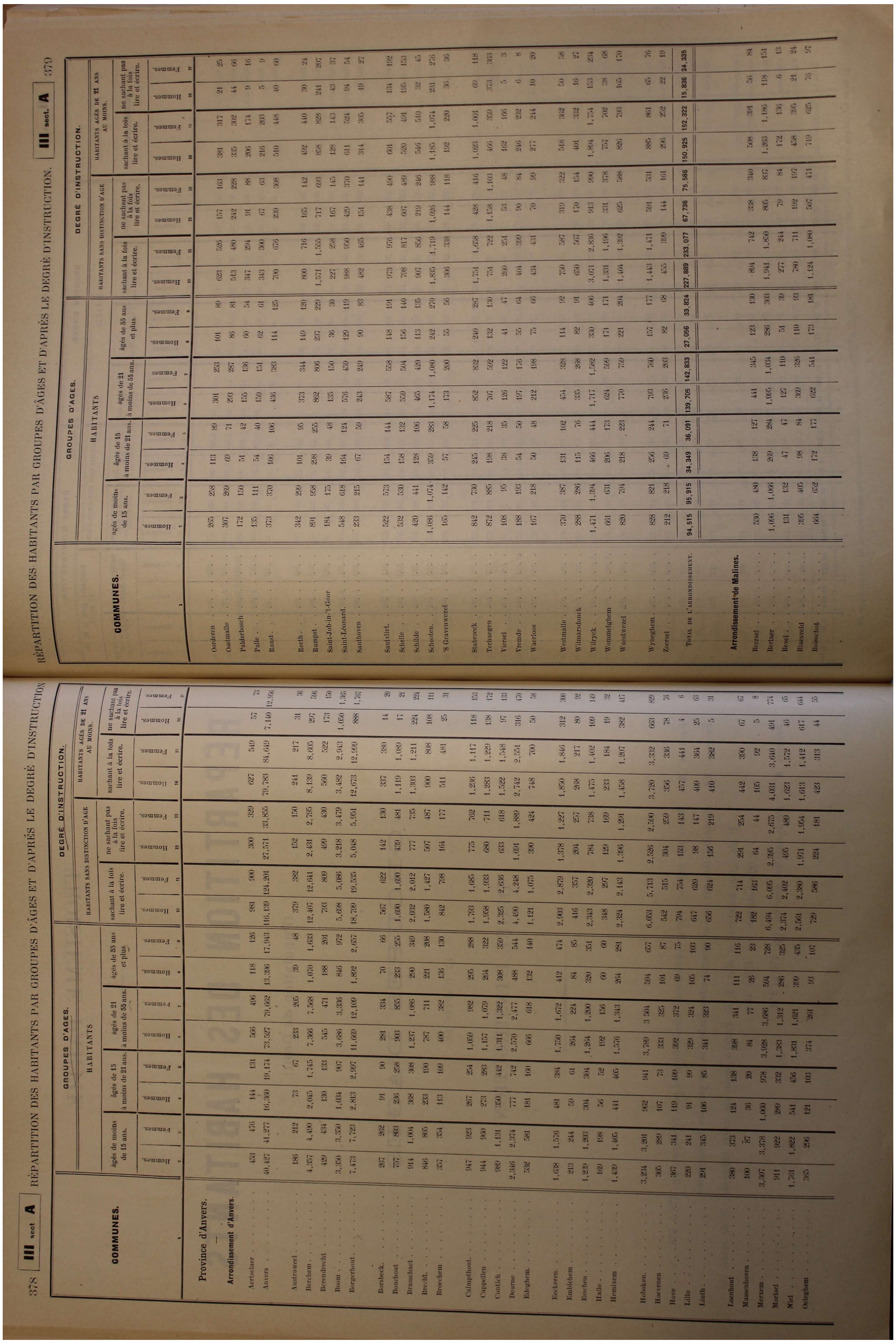


Figure 3.2.: Example of a page from table III of the 1910 Population Census

3.1.4. 1910 Industry and Trade Census

Many industrial and agricultural censuses have been organised in Belgium since 1846[6]. Although these sources contain extensive information on economic activities, most of it is not suitable for spatial analyses. A great share of the numbers provided by these censuses is presented at the country level. When spatial data are available they often correspond to the number of workers by the district or city where they are employed and not by their place of residence. These data are incompatible with the other figures collected for the aggregate dataset, which all refers to the *de jure* population of districts and municipalities.

The 1910 Industry and Trade Census is an exception. It is the only edition that contains information on the number of workers by branch and by municipality of residence. From this census I inputted the **number of workers employed in trade and industry by occupational status (blue-collar and white-collar) and by sex**. These data offer only a punctual view of the Belgian occupational structure. They were only used in order to evaluate the loss in statistical precision from using district-level data in stead of municipalities. The evaluation tests are presented in section 3.3.

3.1.5. Raw data: overview

Table 3.1 shows a summary of the raw data gathered for the construction of the aggregate dataset. All in all, these data offer general information on the demographic, cultural and socioeconomic aspects of the population at a fine geographic scale throughout a long period of time. The period covered by the data leaves out the beginning of the fertility transition in some pioneering spots in the province of Hainaut (Lesthaeghe, 1977), which was prior to 1880; however, it includes most of the fertility transition process, until its end.

Ideally, raw data should provide more precise information. For example, it would have been better to dispose of the number of literate inhabitants above age fifteen instead of the total number; or the number of workers by specific economic branches instead of broad occupational categories. However, whereas more detailed information was available for specific years priority was given to the data available in different years. This was in order to produce time series covering the period between the end of the nineteenth century until the early 1930s.

3.2. Level of analysis and aggregations

The municipal data available in the censuses and in the *Mouvement* correspond to Belgium's old territorial division, composed of about 2,600 small municipalities. It was

[6]See Bracke and Vanhaute (2005) for an inventory of these censuses.

Table 3.1.: Raw data gathered for the construction of the aggregate dataset

Source	Raw data	Period	Level
Mouvement de la population et de l'état civil	Population (by sex)	1880–1935 (annual)	Municipality
	Total births	1880–1935 (annual)	Municipality
	In-migration	1880–1935 (annual)	Municipality
	Out-migration	1880–1935 (annual)	Municipality
	Legitimate births	1886–1935 (annual)	Municipality
	Marriages by age of spouses	1886– 1913 (annual)	Municipality
	Marriages in March	1886–1890, 1896–1900. . . , 1926–1930	Municipality
	Total marriages	1886–1890, 1896–1900. . . , 1926–1930	Municipality
	Deaths before age one	1889–1891, 1899–1901..., 1929–1931	District
Population Censuses	Number of households	1880, 1890, 1900, 1910, 1920, 1930	Municipality
	Native inhabitants	1880, 1890, 1900, 1910, 1920, 1930	Municipality
	Number of literate inhabitants	1880, 1890, 1900, 1910, 1920, 1930	Municipality
	Number of ever-married women	1880, 1890, 1900, 1910, 1920, 1930	Municipality (1880–1910); district (1920–1930)
	Inhabitants by language spoken	1880, 1890, 1900, 1910, 1920, 1930	Municipality (1880–1910); district (1920–1930)
	Age structure (by sex)	1880, 1890, 1900, 1910, 1920	District and cities
	Age structure of married women	1880, 1890, 1900, 1910, 1920	District and cities
	Blue-collars in industry (by sex)	1890, 1900, 1910, 1920	District
	White-collars in industry (by sex)	1890, 1900, 1910, 1920	District
	Blue-collars in trade (by sex)	1890, 1900, 1910, 1920	District
	White-collars in trade (by sex)	1890, 1900, 1910, 1920	District
	Blue-collars in agriculture (by sex)	1890, 1900, 1910, 1920	District
	White-collars in agriculture (by sex)	1890, 1900, 1910, 1920	District
Industry & Trade Census 1910	Blue-collars in industry (by sex)	1910	Municipality
	White-collars in industry (by sex)	1910	Municipality
	Blue-collars in trade (by sex)	1910	Municipality
	White-collars in trade (by sex)	1910	Municipality

not until 1977 that a territorial reorganisation reduced this number to 589, by merging old municipalities into new, broader ones (Institut National de Statistique, 1991).

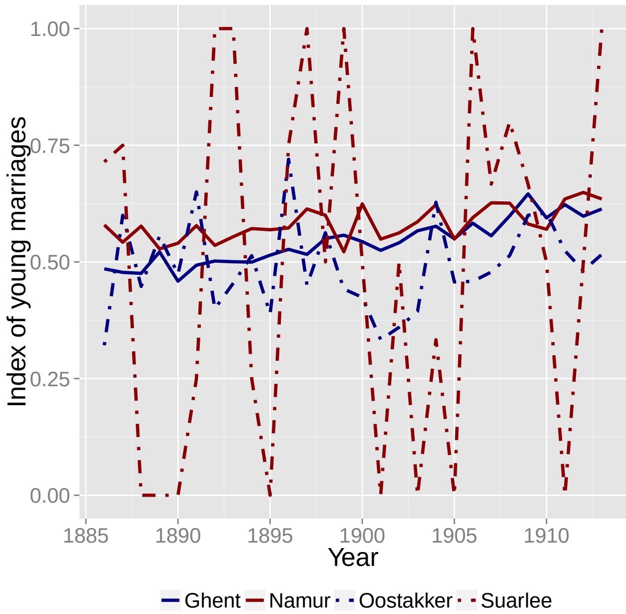
Although the old territorial division offers a very high degree of spatial detail, there are two problems with working at such a fine level. First of all, nearly half of the old municipalities had less than 1,000 inhabitants in 1900. Within these restricted populations the number of demographic events – such as births or marriages – registered over one year can be rather small. Small numbers may produce inaccurate indicators affected by random fluctuations, which makes it impossible to analyse demographic differences over time or across space (Eggerickx and Poulain, 1996). Secondly, the old territorial division was not constant over time: several splittings and mergers took place over the years, which altered the number of municipalities from one year to the next (Vrielinck, 2000).

In this context, before using the raw data collected from the censuses and the *Mouvement*, it was first necessary to examine the potential problems caused by small numbers and to find a solution for the changing territorial division.

In order to evaluate the problem of small numbers I chose a very simple indicator of nuptiality schedule, that can be computed using the municipal data from the *Mouvement* between 1886 and 1913. It is known that marriages were gradually concentrated in younger ages during the fertility transition (Lesthaeghe and Neels, 2002; Matthijs, 2002). In Belgium, the mean age of marriage decreased from 26.7 to 25.2 between 1886–1890 and 1906–1910 (Lesthaeghe, 1977, p. 53). This trend can be expressed by an 'index of young marriages', calculated as the share of women aged less than 25 among the women married over one year (ranging from 0 to 1). Even though this indicator is affected by the age structures of municipalities' populations it serves here to illustrate the problem of small numbers.

Whereas the indicator is easily calculated for large populations, the problems begin as soon as we take smaller municipalities. In fact, the number of marriages over a year can be very small in many municipalities: 63.1% of municipalities registered less than ten weddings in 1886. The reduced number of marriages implies an even smaller likelihood of observing young women among the spouses: in 63.4% of municipalities there were less than five spouses aged less than 25 in 1886. As a result, the indicator of young marriages will be affected by significant random fluctuations, all the more as the municipality is small (Eggerickx and Poulain, 1996).

As an example, let us take four municipalities of different sizes from the old territorial division: the city of Ghent (160,133 inhabitants in 1900) and the nearby town of Oostakker (4,406); and the city of Namur (31,196) and the adjoining village of Suarlée (479). The evolution of the indicator of young marriages between 1886 and 1913 (figure 3.3) is stable for both cities: even though Namur's population is five time smaller than that of Ghent, it is still large enough to produce a coherent yearly time series. The town of Oostakker presents moderate fluctuations in the indicator. As for the village of Suarlée, the evolution of the indicator seems to be entirely random. The number of marriages is so small that in certain years the only marriage concerns a young women (index = 1). For other years there are no young women among the spouses (index = 0). This example shows that the small numbers do not allow the comparison of a simple indicator in space and time: the random fluctuations are so wide that it is impossible to distinguish the real differences in marriage behaviour from one year to the other or from one municipality to the other.



Source: *Mouvement de la population et de l'état civil*

Figure 3.3.: Share of young spouses among the women married over one year in four municipalities (1886–1913)

There are three possible solutions for the problem of small numbers: spatial smoothing techniques, temporal aggregation and spatial aggregation.

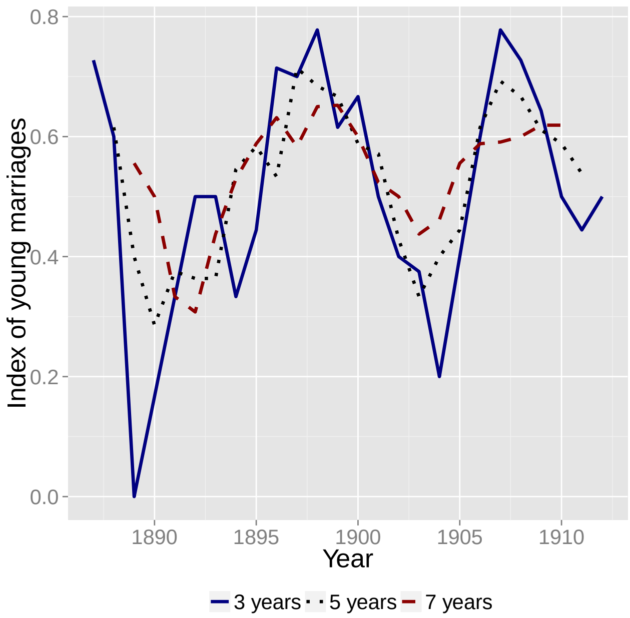
Spatial smoothing techniques have been used to calculate indicators of 'rare' events, such as the share of people over 100 years old in municipalities (Poulain et al., 2009) or mortality rates by specific death causes (Kafadar, 1996). The general idea of such methods is to seek complementary information in the closest spatial units in order to calculate more accurate indicators. In the example of young marriages the smoothing could be done for each one of the small municipalities in seeking complementary information about marriage in the nearest municipalities. The concept of 'proximity' plays an important role. Spatial smoothing based on geographic distance might exaggerate the spatial clustering of social phenomena and hide important differences at the local level: as spatial units that are close tend to resemble, the method might reinforce resemblances and overestimate the spatial dependence of an indicator (Carrington et al., 2007). An alternative would be to consider the similarities in terms of socioeconomic and cultural features and seek the complementary information not in the nearest but in the most similar spatial units (Sanderson et al., 2010). Either way, in the case of our raw data spatial smoothing would not be a viable option. The method would have to be applied for each one of the indicators in the dataset and for each year of observation. In addition, smoothing would have to be combined with some other solution for the changing territorial division over the period of study.

Temporal aggregation consists of adding a certain number of years of observation, for instance using moving averages. In the case of our raw data this strategy would allow inflating the municipalities' numbers in order to reduce random fluctuation of the indicators. Nonetheless, for small municipalities several years have to be added in order to obtain satisfactory results. In the case of Suarlée (figure 3.4), moving averages over three years are not enough to reduce random variations in the time series of the young marriages index. We have to add seven years in order to produce a sufficiently smooth series. In sum, although this strategy would allow to maintain the high level of geographic detail of the raw data, it would imply an important loss in their temporal detail. Once again, temporal aggregation alone would not solve the problem of the changing territorial division over time.

The third strategy – *spatial aggregation* – consists of merging spatial units in order to augment population numbers. This strategy necessarily results in some loss of the spatial detail of the original data. However, it presents some convenient advantages in our case. Firstly, the aggregation of old municipalities would allow to define a constant territory over the period covered by the dataset. Secondly, old municipalities are so small that they can be merged into new units that are large enough to solve the problem of small numbers, but still detailed enough to display the spatial diversity of the territory.

In the light of the options presented above I chose to operate a spatial aggregation with the raw municipal data compiled from the censuses and from the *Mouvement*. The idea was to create a constant territorial division between 1880 and 1935, in such a way that the random fluctuations caused by small numbers could be minimised, whilst still maintaining a maximum level of spatial detail.

A logic option would be to merge the old municipalities from the dataset into the new broader municipalities created since the territorial reform of 1977. However, a problem with the new municipal division is that it mixes urban centres and their rural surroundings. For example, the old municipalities of Namur and Suarlée belong nowadays to the new municipality of Namur; the urban centre of Ghent has also been merged to its surrounding villages and towns, including Oostakker. The merger of urban and rural units implies a significant loss in the spatial precision of the dataset. In fact, as we have seen in the literature review, the mechanisms of fertility change are



Source: *Mouvement de la population et de l'état civil*

Figure 3.4.: Share of young spouses among the women married in Suarlée (1886–1913): Moving averages over three, five and seven years

expected to be different in cities and rural areas. Structural shifts would be more likely to affect urban centres first and diffuse from there towards smaller towns. Also, the weight of social and moral control would tend to remain stronger in rural areas and slow down fertility changes in isolated zones.

In order to keep as much of the spatial diversity as possible the aggregation was operated in two steps. Firstly, all the old municipalities with more than 10,000 inhabitants in 1900 were isolated. These urban units were kept unchanged in the dataset. In a second phase all the other old municipalities were merged into the new municipalities. For example, the old cities of Ghent and Namur were kept as they were in the old municipal division; the villages surrounding these cities that belong nowadays to the new municipalities of Ghent and Namur were respectively merged into 'Rural Ghent' (including Oostakker) and 'Rural Namur' (including Suarlée). In summary, the aggregation proposed here produces a constant territorial division between 1880 and 1935. The attempts solve the problem of small numbers while still maintaining the spatial detail of the dataset – in particular the opposition between urban and rural.

Another advantage of this choice is that the splittings and mergers of old municipalities over the period 1880–1935 occurred inside the limits of the new municipalities[7] (Institut National de Statistique, 1991). Therefore, the new municipal division is not affected by the scissions and mergers occurred during the period of study. On the other hand, it is an implausible task to take into account the numerous rectifications of municipal borders over the years. We can nonetheless suppose that most of the border alterations occurred within the limits of the new municipalities. Moreover, population transfers between municipalities due to rectifications have little impact on relative numbers, as numerators and denominators are rectified at the same time.

In practice, the spatial aggregation was conducted as follows. Each old municipality in Belgium had an identification code used by the National Institute of Statistics. During the territorial reform of 1977 new codes were attributed to the new municipalities. It is thus possible to link each old code to the new municipality they belong to nowadays. For each year of observation of our dataset the old codes were linked to new ones, (except for the old municipalities with more than 10,000 inhabitants in 1900), i.e. each one of the old municipalities was linked to the new unit they belong to. This way, the raw data at the old municipal level could be simply added up according to the new municipal division.

The territorial division proposed for the aggregate dataset is presented in figure 3.5. It consists of 645 spatial units[8] – 88 urban centres (that were kept unchanged) and 559 units resulting from the mergers of old towns and villages. As a matter of simplification these new spatial units will be referred to as 'municipalities' or '*communes*' throughout the thesis.

The population numbers after the spatial aggregation are sensibly larger: more than half of the new spatial units had more than 6,000 inhabitants in 1900 and only four of them had less than 1,000. However, these new figures might not be enough to completely solve the problem of small numbers for all the indicators. Going back to the example of the index of young marriages, 143 of the new spatial units registered less than ten marriages in 1886. In this case, moving averages over a limited number of years can be used to smooth the remaining randomness of time series. Figure 3.6 illustrates the evolution of the index of young marriages after the spatial aggregation using moving averages over three years (as a reminder the cities of Ghent and Namur remained unchanged, whereas the towns of Oostakker and Suarlée were merged into 'Rural Ghent' and 'Rural Namur' respectively). The graphic shows a much smoother evolution of the indicator, which does not seem to be affected by random fluctuations.

In summary, the raw data compiled from the censuses and the *Mouvement* at the

[7] The only exceptions were the small *communes* of Caggevine and Assent, which were split in several parts and redistributed beyond the new municipal borders. Therefore, these old municipalities were excluded from the dataset.

[8] The new municipality of Herstappe was excluded from the dataset because of its very small population (148 inhabitants in 1900). Moreover, the German-speaking municipalities added to the Belgian territory after the First World War were not included in the dataset.

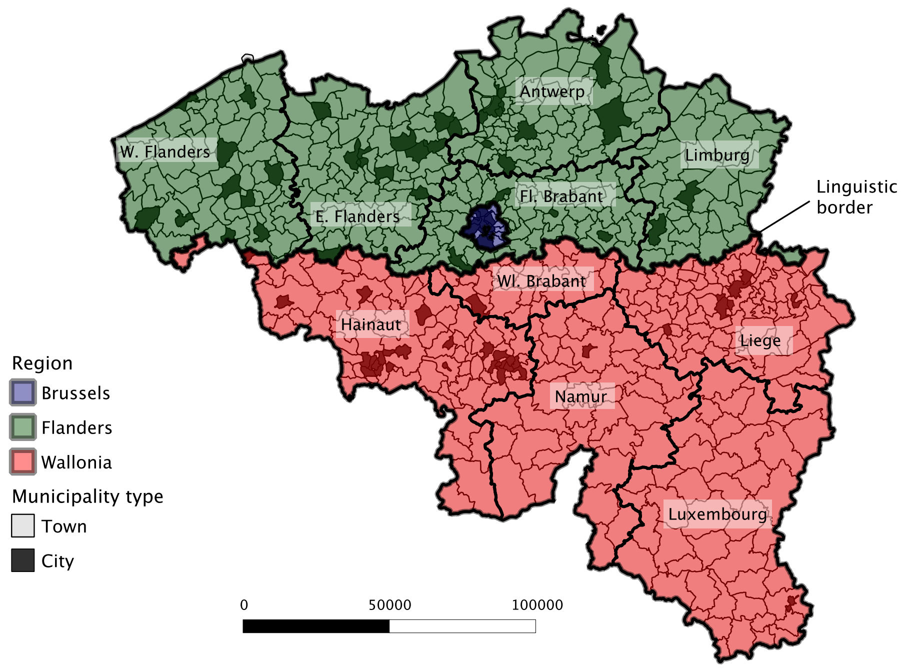


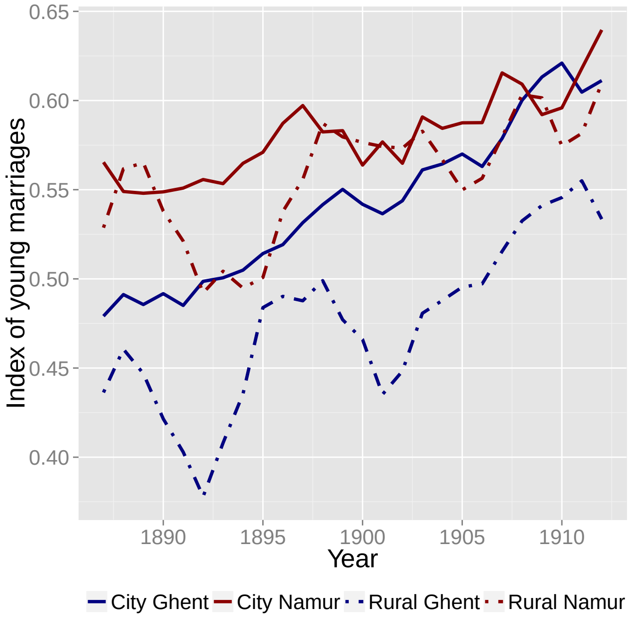
Figure 3.5.: Territorial division used for the aggregate dataset

level of the approximately 2,600 old municipalities from 1880 to 1935 cannot be directly used to calculate indicators. Not only were the old municipalities too small, but they also constantly changed over time. Therefore, the old municipalities were aggregated into 645 larger spatial units in order to create a constant territorial division throughout the time-span of the data and also to minimise the random fluctuations due to small numbers. In the case of indicators for which the numbers are still too small after the mergers, temporal aggregation can be used to smooth random variations.

3.3. Aggregate indicators

Having defined a constant territorial division, the data compiled could finally be used to compute the indicators that will serve in the spatial-temporal analysis of the fertility decline in Belgium. These indicators must operationalise four groups of concepts:

- reproductive behaviour;
- socioeconomic aspects of the population;
- cultural attributes;
- networks features of municipalities.



Source: *Mouvement de la population et de l'état civil*

Figure 3.6.: Share of young spouses among the women married in four municipalities (1886–1913):
Moving averages over three years

The indicators within these four categories are presented below. Each indicator is illustrated with a map offering an overview of its spatial distribution at one point in time, around 1910 (figures 3.7 to 3.10).

3.3.1. Reproductive behaviour

Marital fertility

Marital fertility is a key information in this research. The fertility transition is a process in which individuals deliberately control their parity: fertility levels decline as a result of conscious limitation of births. For this reason, studies on fertility transition have traditionally used indicators of marital fertility. The idea is to measure the reproductive choices within married couples, i.e. excluding out-of-wedlock births that would not reflect deliberate reproductive strategies (at least not at the time).

In this thesis the fertility level of municipalities was estimated by Coale's marital fertility index. This indirect indicator was first proposed in the European Fertility Project (Coale and Watkins, 1986, app. B) and is still widely used in historical fertility studies at the aggregate level.

The **marital fertility index** (I_g) indicates how close the fertility of married women in a given place is to the 'natural' fertility level. The Hutterites' fertility levels are used as a reference of natural fertility. The index is calculated as follows:

$$I_g = \frac{b_l}{\sum_{a=15}^{49} m_a \cdot f_a} \tag{3.1}$$

where b_l is the number of legitimate births, m_a is the number of married women at age a and f_a the Hutterite's fertility rate at age a. The index compares the actual number of legitimate births to the theoretical number of births that would be observed if married woman did not control their fertility. Its values can theoretically vary between 0 and 1, although some studies have found superior values in Europe.

Guinnane et al. (1994) highlighted two important limitations of this indirect measure. First, the indicator is not independent of the nuptiality schedule of populations: the age distribution of married people can affect its value. Second, changes in I_g do not necessarily reflect conscious limitation of births. For example, if breastfeeding becomes more widespread within a population the fertility index would decrease without deliberate birth limitation by married couples.

Despite these potential problems Guinnane et al. (1994) acknowledge the interests of I_g, especially when data availability is limited. In our case, using the data compiled from the *Mouvement* and the censuses it is possible to compute this indicator with a fine level of spatial and temporal detail. This will be crucial for the analyses of the spatial-temporal patterns of fertility decline.

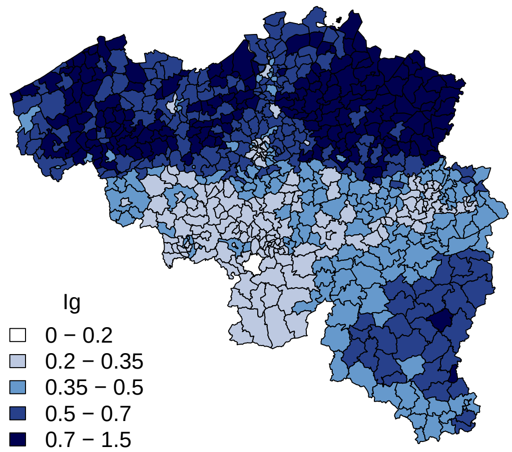
The marital fertility index was computed as follows. The Hutterite's fertility rates by age (f_a) are known (Coale and Watkins, 1986, p. 154). The number of legitimate births (b_l) by year and municipality was compiled from the *Mouvement* between 1886 and 1935 (except for the war years, 1914–1918). In order to avoid random fluctuations due to small numbers I used a three-year aggregation of b_l for each municipality centred on each year between 1887 and 1934.

The number of married women by age – m_a – was not available at the municipal level. These data were thus compiled from the population censuses of 1890, 1890, 1900, 1910 and 1920 at the district level, distinguishing cities and towns in each district. By linear interpolation annual standard age distributions were created for the period 1887–1934 and assigned to the municipalities according to their district and status (city/town).

I assume that variations in age structures among municipalities of a same district are minimal and have little effect on the index values. In order to evaluate the validity of this assumption I analysed a more general nuptiality indicator – the share of ever-married women among the female population aged at least fifteen years old – that could be compiled for both the municipal and district levels from the 1910 Population

Census. The between-districts variance of this indicator represents 77% of the between-municipalities variance. In other words, taking the intensity of nuptiality at the district levels implies only a 23% loss of municipal variation.

In the end, we obtain an annual series of I_g for the 645 municipalities of the dataset between 1887 and 1916 and between 1920 and 1934. Figure 3.7 depicts the spatial distribution of I_g at mid-period.



Sources: *Mouvement de la population et de l'état civil* and Population Censuses

Figure 3.7.: Marital fertility index I_g (1910)

Nuptiality schedule

The fertility transition was accompanied by deep changes in nuptiality schedules (Lesthaeghe, 1977; Matthijs, 2002). In preindustrial societies, marriages were late and non-universal. In order to marry individuals relied on the heritage passed by their parents. Marriages depended on the prevailing inheritance system and were generally late and not accessible for everyone (Lesthaeghe, 1977). As industrialisation unfolds the growth of wage labour frees individuals from the old constraints imposed by inheritance systems (Folbre, 1983; Lesthaeghe and Neels, 2002). Nuptiality becomes increasingly concentrated at younger ages and more universal – a process that Lesthaeghe defines as the 'modernisation of nuptiality' (Lesthaeghe, 1977, p. 46).

Nuptiality has thus a twofold relation with marital fertility. On the one hand, the nuptiality schedule of a population has a direct influence on marital fertility levels: the more younger women marry, the more they are exposed to the 'risk' of bearing children. On the other hand, fertility decline is expected to be accompanied by earlier and more universal marriage patterns. Both the fertility transition and the modernisation of nuptiality seem to be connected in a common process of social transformation, directed by industrialisation and cultural change.

Belgian data offer different possibilities to compile nuptiality indicators. This includes the share of women aged 20–24 in the total female population at the district level (Lesthaeghe, 1977) and the share of ever-married women among the female population aged at least fifteen years old at the municipal level. However, nuptiality indicators were not included in the final analyses of this thesis. Whereas nuptiality schedule is a direct determinant of fertility itself, the modernisation of nuptiality is deeply intertwined with the adoption of modern fertility behaviour within the fertility transition. From a spatial-temporal perspective the changes in marriage patterns are a concomitant process, rather than a determinant of fertility change. Moreover, nuptiality schedules are already accounted for in the calculation of the marital fertility index I_g.

3.3.2. Socioeconomic indicators

Education

The **literacy rate** is the only education indicator that can be calculated with the available data. It was computed at the municipal level using census data from 1880 to 1930. The indicator expresses the share of literate inhabitants in the total population.

It is important to acknowledge some limitations of this indicator and of the concept of education in general.

First, it is not clear who the censuses considered as literate. If a person that could only write his or her name was considered literate, this indicator does not say much about the education level of the population.

Second, the literacy rate is affected by the age structure of the population. Obviously, young children are less likely to be literate, thus the younger the age structure of a municipality, the more illiterate inhabitants there will be. It would be preferable to have the number of literate inhabitants aged fifteen years old and more. However, this information was only available in certain editions of the census; in order to construct a consistent time series, more generic information had to be chosen.

Finally, because of the particularities of the Belgian education system education can have a twofold relation with fertility. On the one hand, we could expect higher education to be associated with lower fertility. Education would give individuals access to information, contribute to the emancipation of old social norms and provide some autonomy to make conscious reproductive decisions (McDonald, 2000; Mason, 2001).

On the other hand, as Lesthaeghe (1977) points out, schools in Belgium were often controlled by the Catholic Church. In this sense, education in the Catholic system could have contributed to moral and social control, i.e. social influence inhibiting the adoption of modern reproductive behaviour.

Infant mortality

Infant mortality is expected to have a positive relationship with fertility levels. The death of a young child interrupted the contraceptive effect of breastfeeding, provoking 'fertility-boosts' in the short run (Knodel and van de Walle, 1967; van de Walle, 1986; Galloway et al., 1998; Reher, 1999). Furthermore, as infant mortality decreases and more children survive, couples have to bear less children in order to attain their desired family size (Easterlin and Crimmins, 1985; van de Walle, 1986; Reher, 1999).

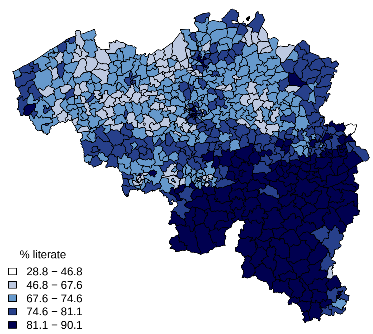
The **infant mortality rate** is calculated as the ratio between the number of deaths before age one and the total number of living births. As mentioned in section 3.1, the input of infant mortality data from the *Mouvement* is an extremely time-consuming task at the municipal level. For this reason the data were compiled at the level of the 41 Belgian districts. Because of the small numbers of infant mortality in the later years rates were calculated over three years periods in 1889–1901, 1909–1911, 1919–1921 and 1929–1931.

Infant mortality data was compiled at the municipal level for the period 1909–1911 in order to evaluate the amount of spatial detail that is lost as a result of choosing districts over municipalities. The map at the municipal level (figure 3.8b) shows a strong spatial concentration of infant mortality. The variance of the indicator at the district level represents 95% of the variance at the municipal level. In other words, working with districts results in a limited loss of the spatial diversity. Moreover, tests with F-statistics have shown that municipalities within the 41 districts are highly homogeneous in terms of infant mortality (the within-districts variances are far smaller than the between-districts variance). In summary, the choice of computing infant mortality at the district level has little effect on the statistical precision of the indicator.

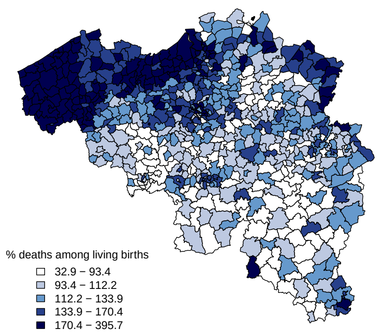
Industrialisation and female labour

As mentioned in section 3.1, economic data availability is limited in Belgium during the period of the fertility transition. Censuses provide information on the number of workers by more or less detailed economic branches at the district level, but the categories of branches were constantly altered from one census to the next (Bracke and Vanhaute, 2005; Lesthaeghe, 1977). Furthermore, there are no time series of wages available in Belgium, unlike in Sweden (Dribe, 2008) or in Bavaria (Brown and Guinnane, 2002).

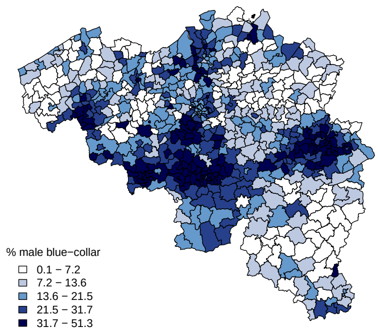
The data compiled from the censuses between 1880 and 1920 at the district level consist of the number of workers in three broad categories: trade, industry and



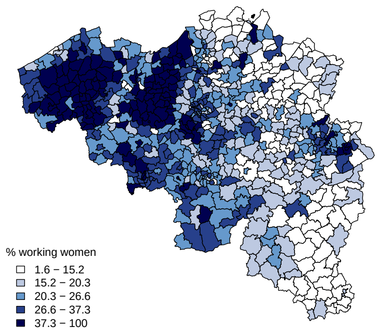
(a) Literacy rate (1910)



(b) Infant mortality rate (1909–1911)



(c) % male blue-collar in industry (1910)



(d) Female labour (1910)

Sources: *Mouvement de la population et de l'état civil*, Population Censuses and 1910 Industry and Trade Census

Figure 3.8.: Socioeconomic indicators

agriculture. Workers can be distinguished by occupational status (blue-collar and white-collar) and sex.

The **proportion of male blue-collar workers in the industry** among the active population (15–65 years old) is used as a proxy of the districts' industrialisation level. This is a key indicator to approach structural effects on fertility behaviour. The rise in wage industrial labour would have altered couple's preferences in family size. As there are fewer opportunities for children to work in an industrial context childbearing becomes economically disadvantageous (Bongaarts and Watkins, 1996; Kirk, 1996). Also, the rising material aspirations in the industrial life would be incongruent with a large number of children: high fertility would become an obstacle to social mobility (Eggerickx, 2004).

A second indicator represents the **female labour force**. It is calculated as the share of female workers in trade and industry[9] among the active female population. The rise in female labour might have altered the costs of childrearing, which would have encouraged fertility limitation (Folbre, 1983). In addition, working women would be more familiarised with the world outside the home and have more opportunities to learn about the economic benefits and the moral acceptability of limiting their number of births (McDonald, 2000; Mason, 2001).

The indicators of industrialisation and of female labour could be calculated at the municipal level for 1910 using the data compiled from the Industry and Trade Census. The municipal data in 1910 were useful to assess the loss of statistical precision imposed by the use of districts instead of municipalities.

Female labour was highly concentrated in space, as suggested by the municipal map in figure 3.8d. The variance loss that results from using districts, compared to municipalities, is fairly limited (27%) and within-districts variances of most districts are in average eight times smaller than the between-districts variance (F-tests).

In contrast, the loss in statistical precision is much higher in the case of the proportion male blue-collars: half of the variance of the industrialisation indicator is lost when we pass from municipalities to districts. However, within-districts the variances are in average twice as small as the between-districts variance (the mean F-test value of districts is 2.4). Furthermore, the correlation between the industrialisation indicator and the marital fertility index in 1910 is stronger when district values are used instead of municipalities (-0.59 and -0.49 respectively). This means that the impact of the districts' industrialisation level on municipalities' fertility level is likely to be overestimated. This does not represent a major problem for the analyses, as their aim is to measure diffusion effects net of industrialisation and other factors. If the impact of industrialisation is overestimated, the evidence of diffusion in the statistical analyses

[9] Female labour in agriculture were poorly registered in the censuses (Lesthaeghe, 1977) and the quality of the figures varies across the country. Moreover, agricultural work was often associated to the household production. In to avoid potential bias agricultural work was excluded from this indicator.

will still be safely estimated.

3.3.3. Cultural indicators

Languages

The linguistic distribution in space is a powerful information in the dataset. The prevalence of Dutch in the north and of French in the south of the country attests to the existence of two separate linguistic and cultural communities in Belgium, divided by a linguistic border.

It is known from previous research that secular ideas spread much earlier within French-speaking populations (Lesthaeghe and Lopez-Gay, 2013)and that the southern districts were also forerunners in the fertility transition (Lesthaeghe, 1977). Evidence suggests that the presence of Francophones in Flanders contributed to the spread of modern fertility behaviour. The use of French became increasingly widespread among the Flemish upper classes until the First World War (Lesthaeghe, 1977). This bilingual segment of the Flemish population were earlier adopters of new fertility behaviour in Flanders. It is possible that they passed new ideas and attitudes in respect to fertility to lower classes. In addition to that, Francophone migrants living in Flanders – including the working class – seem to have brought with them new ideas and attitudes and contributed to the spread of modern fertility among the Flemish population (Van Bavel, 2004a).

Linguistic minorities were also present in Wallonia. These include migrants coming from Flanders and from other European countries, but also a German-speaking population along the German and Luxembourg borders (Lesthaeghe, 1977).

Data from the censuses offer different possibilities to operationalise the effects of the linguistic distribution. In his monograph Lesthaeghe (1977) calculated two separate indicators for Flanders and Wallonia, as he ran separate statistic analyses for the two regions. For Flanders he used the proportion of people aged fifteen and more with a knowledge of Dutch only. As expected, this index showed a strong and positive correlation with fertility levels. The index for Wallonia denoted the proportion of people above age fifteen with a knowledge of French only, which had a weaker but negative correlation with fertility.

As mentioned before, this thesis aims at analysing the fertility transition in Belgium as a whole. Therefore, we need a common indicator of language that can apply to both sides of the linguistic border. For this reason I chose to compute the **proportion of people with a knowledge of French (as first or second language)**. In Flanders this indicator includes the bilingual upper classes, as well as the Walloon migrants. In Wallonia the indicator includes the migrants and linguistic minorities that had acquired some knowledge of French at the time of the census. We can assume that these segments of the Walloon population were embedded enough in the society and thus exposed to the prevalent attitudes and ideas. Globally this indicator expresses the population's exposure to the 'Francophone world' and its innovative ideas about secularisation and attitudes in respect to fertility.

This indicator was computed at the municipal level using census data from 1880 to 1930. Linguistic information for individuals above fifteen years were not available in all censuses. As a result, the index reports the share of French-speaking of all ages among the total population.

Secularisation

The Belgian censuses do not provide any direct information on religious practices that can be used in spatial analysis[10]. In this context researchers have used proxies to approach religiousness and secularisation[11].

As marriages during Advent and Lent were proscribed by the Catholic Church, the intensity of marriages in December and in March can be used as a proxy for the respect of religious norms and the moral and social control imposed by the community (Lesthaeghe, 1991). The indicator – called 'marriages in Lent and Advent index' – has been used by Lesthaeghe at the district level in his recent works and has shown to be a good proxy for secularisation (Lesthaeghe and Neels, 2002; Lesthaeghe and Lopez-Gay, 2013).

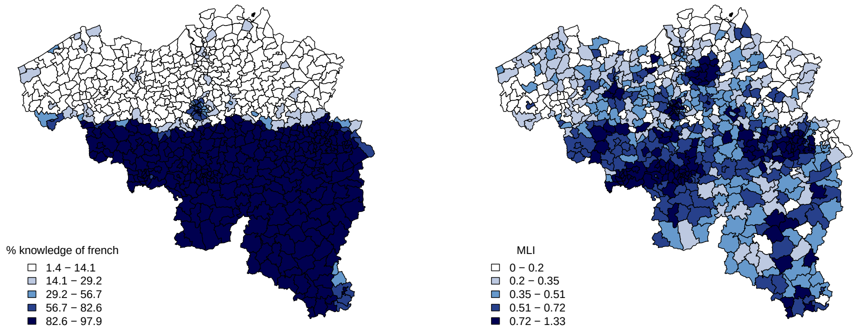
In order to reduce the input time I selected only the marriages in March, because the respect of marriage ban during Lent was shown to be more subjected to moral and social control compared to Advent (Eggerickx et al., 2008). The **marriages in Lent index** (MLI) is obtained by the number of marriages in March (M_{march}), divided by the mean monthly number of marriages during one year:

$$MLI = \frac{M_{march}}{\frac{M_{total}}{12}} \tag{3.2}$$

The index was computed for municipalities by five-year periods in order to avoid small numbers and to smooth the variation of the liturgical calendar (Lent does not always exactly correspond to the month of March): 1886–1890, 1896–1900, 1906–1910, 1919–1923 and 1926–1930.

[10] For example, in Prussia census data contains the number of Catholics by district (Goldstein and Klüsener, 2014).

[11] A good proxy for secularisation would be the proportion of votes for socialist parties that can be obtained at the level of the electoral districts from the Election Atlas (De Smet et al., 1958). Unfortunately this information is only available from 1919 on, which correspond to the the latter part of the fertility transition in Belgium – see also Lesthaeghe (1977).



(a) % francophone (1910)　　(b) Marriages in Lent index (1906–1910)

Sources: *Mouvement de la population et de l'état civil* and Population Censuses

Figure 3.9.: Cultural indicators

3.3.4. Networks indicators

Intensity of social interactions

A first indicator of the social networks features of municipalities is the **population density**. This indicator is used as a proxy of the intensity of social interactions: in spatial units where population density is high inhabitants would have more opportunities for social interactions and new ideas about fertility behaviour should flow more easily.

The population density is obtained by the ratio of the total population to the municipality area. It was computed with yearly data from the *Mouvement* between 1886 and 1913 and between 1919 and 1935.

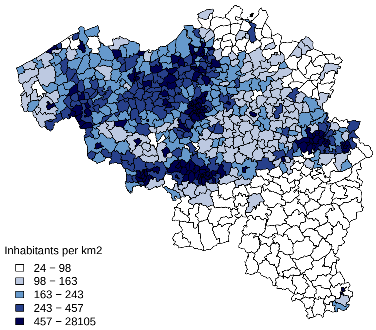
Heterogeneity of social networks

Population heterogeneity resulted from spatial mobility can contribute to the diffusion of ideas and attitudes in respect to fertility. As many empirical studies have shown, diffusion can operate more freely within heterogeneous networks – or 'weak ties'. People from other backgrounds can bring with them new ideas and values about the benefits and moral acceptability of fertility limitation.

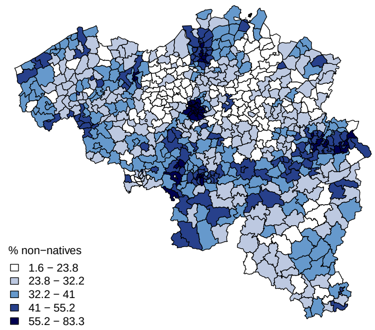
Ideally indicators should contain information on migrants' background. For example, migrants coming from forerunner areas in fertility transition would be more likely to contribute to the diffusion of new ideas. Unfortunately, the data available in the aggregate sources report total number of migrants, regardless of their origin.

The *Mouvement* contains annual numbers on in- and out-migration at the level of the old municipalities. This information offers the possibility to calculate an indicator of mobility intensity (the sum of in- and out-migration divided by the population). However, after the spatial aggregation operated in the dataset, these data can no longer be used. When we aggregate the data migration numbers include non only the movements from and to other spatial units, but also the changes of residence between old *communes* within the new spatial units.

As an alternative I used the census data from 1880 to 1930 to compute the **proportion of non-native inhabitants** on the total population of municipalities. The number of non-native inhabitants (i.e. residents born in another *commune*) is also affected by the spatial aggregation: for a given municipality of our space an individual considered as non-native might have been born in another village of the same municipality or elsewhere in the country. Even so, this is still a pertinent indicator. It denotes the share of the population that does not live in the same place of birth. Even if the place of birth is inside the same new municipality, it is likely that an individual counted as non-native was socialised in another place, and is less embedded in the local social network from the community where he or she lives. Put simply, we can expect that new attitudes and ideas will spread more rapidly in communities where social interactions are heterogeneous; the proportion of non-natives is a way to measure the heterogeneity of municipalities.



(a) Population density (1910)



(b) % non-natives (1910)

Sources: *Mouvement de la population et de l'état civil* and Population Censuses

Figure 3.10.: Networks indicators

3.3.5. Aggregate indicators: overview

Table 3.2 brings an overview of the indicators computed in the aggregate data. Each indicator is illustrated by a map in figures 3.7 to 3.10.

It is important to highlight at least three limitations of the indicators set. First, information on marital fertility is only available from 1886 on, which leaves out the beginning of the fertility transition in municipalities of the Hainaut province. Second, as pointed out throughout this section, many of these indicators provide only generic information on socioeconomic and cultural factors. Third, although our ultimate purpose is to investigate individuals' attitudes and behaviour in respect to fertility, the indicators are based on aggregate data. It is important to keep in mind that the correlation observed at the aggregate level are not necessarily true at the individual level (Robinson, 1950; Steel and Holt, 1996).

Despite its limitations the indicators set is very rich in terms of spatial and temporal detail. It is composed of unpublished time series of indicators covering 50 years, many of them at the level of 645 municipalities. Therefore, it offers great potential to the space-time analysis of the Belgian fertility transition. Furthermore, the dataset provides a dynamic view of fertility decline and the associations between indicators can be studied not only from a cross-sectional perspective but also from a temporal one, taking into account the ordering of demographic, structural and cultural changes over the years.

Table 3.2.: Aggregate indicators computed from the raw data

Theme	Indicator	Period	Level
Fertility	Coale's marital fertility index (I_g)	1887–1934 (annual)	Municipality
Socioeconomic	Literacy rate	1880, 1890, 1900, 1910, 1920, 1930	Municipality
	Male blue-collars in industry	1890, 1900, 1910, 1920	District (1890–1920); municipality (1910)
	Female labour in industry and trade	1890, 1900, 1910, 1920	District
	Infant mortality rate	1889–1901, 1909–1911, 1919–1921, 1929–1931	District
Cultural	% Francophone	1880, 1890, 1900, 1910, 1920, 1930	Municipality (1880–1910); district (1920–1930)
	Marriages in Lent index	1886–1890, 1896–1900, 1906–1910, 1919–1923, 1926–1930	Municipality
Networks	% non-native inhabitants	1880, 1890, 1900, 1910, 1920, 1930	Municipality
	Population density	1880–1935 (annual)	Municipality

Chapter 4.

The individual dataset

Notwithstanding the richness of the Belgian historical source material, systematic efforts of compilation of micro-level data are lacking in Belgium, especially compared to other Western countries. For example, the North Atlantic Population Project is a large-scale initiative that has managed to digitise complete census individual data from the late nineteenth century and early twentieth century for Canada, England and Wales, Iceland, Norway, Sweden and the United States (Ruggles et al., 2011). In the Netherlands a representative sample from population registers and vital records has been compiled in the Historical Sample of the Netherlands, offering detailed longitudinal data for different parts of the country (Mandemakers, 2006). In the case of Belgium, micro historical data has only been gathered by punctual studies at the local level, such as for the Charleroi industrial area (Eggerickx, 2004), the town of Leuven (Van Bavel, 2002), the city of Antwerp (Matthijs and Moreels, 2010) and rural and urban areas in the Province of Liège (Alter, 1988; Leboutte, 1988; Neven, 2003; Oris, 1988, 1991). However, at the scale of the country few extensive attempts have been done so far to make the rich historical data patrimony available for statistic analysis.

Fortunately, complete digitised micro data from recent censuses in Belgium offer the possibility to study fertility behaviour in the past using a retrospective approach. In the censuses of 1981, 1991 and 2001, female respondents were asked about the number of children they had ever borne, as well as the year in which each birth took place. This information allows to reconstruct the entire reproductive history of several female birth cohorts. Neels (2006), for example, used the 1991 Census in a thorough longitudinal analysis of reproductive and family strategies between 1960 and 1990. Costa et al. (2011) and Van Bavel (2014) went further back in time with the 1981 Census and reconstructed fertility behaviour of women born since the beginning of the twentieth century[1].

[1] Studies on the fertility transition in Italy used a similar approach based on the 1971 Census (Caltabiano

In the case of this thesis micro-level data from the 1981 Census (Willaert and Deboosere, 2008) can be used to investigate the impact of diffusion on individual fertility behaviour during the latter part of the fertility transition. Section 4.1 discusses the possibilities offered by the census, as well as the many limitations imposed by the data in respect to our purposes. After this discussion section 4.2 presents the individual data selected for the analyses. Finally, section 4.3 brings an overview of the individual dataset and its potential for the analysis of diffusion effects in combination with the aggregated dataset.

4.1. The 1981 Census: possibilities and limitations

The 1981 Census can be used in this thesis to analyse the fertility behaviour of married women born between 1890 and 1899. These are the oldest women present in the census, aged between 80 and 90 years old in 1981. The reproductive life of these birth cohorts spread out roughly between 1920 and 1940, which corresponds to the latter part of fertility transition in Belgium.

Apart from the retrospective information about reproductive histories, the censuses contain useful information on education and migration. Education information can be used to compare the adoption of modern fertility among low- and high-educated women and especially the differential impact of diffusion, as well as cultural and structural factors, across different education levels. Information on migration histories is essential to locate women in space and to link their individual reproductive behaviour to the spatial variables from the aggregate dataset.

However, there are important limitations imposed by the census data. First of all, a retrospective approach of fertility can involve a series of biases. Moreover, the census contains limited information on migration histories, which makes it impossible to situate the reproductive behaviour of all women in space.

4.1.1. Potential biases in retrospective fertility data

The reconstruction of fertility histories using retrospective data from censuses can be biased by a series of factors (Wunsch, 2001). First, the nonresponse on the question about the number of children may lead to inaccurate estimates, especially if women who did not respond had different fertility behaviour compared to the ones who did respond. A second potential source of bias is the misreporting of the number of children ever born, which can be due to memory gaps or to the omission of live-born children who died at a young age. Moreover, the retrospective approach can be affected by migration and mortality. As the census concerns only the population present in 1981, there is obviously no information on the women who had died or out-migrated before

and Dalla-Zuanna, 2013) and on Italian fertility survey of 1961 (Breschi et al., 2013).

this date. If these unobserved women had specific reproductive behaviours, fertility estimates will be biased.

To evaluate the overall bias of the census retrospective data we can compare the cohort total fertility calculated with the 1981 Census to the cohort total fertility rates based on vital records[2], as shown on figure 4.1. Unfortunately, the rates based on vital records are not available for birth cohorts before 1905. Although the two series are very close, it is clear that the census underestimates fertility levels of older birth cohorts. The cohort total fertility based on the census is approximately 4% below the vital records estimates.

Sources: Sardon (1991) and 1981 Population Census

Figure 4.1.: Cohort total fertility estimates from the 1981 Census and from the vital records

In theory, the underestimation of fertility could be caused by any of the factors mentioned above: nonresponse, misreporting, mortality and/or migration. Even though we cannot determine what causes the bias, we can speculate about the contribution of each one of these factors.

Whereas nonresponse was higher among older cohorts – above 4% (Van Bavel, 2014, p. 935) –, it is unlikely that the underestimation of fertility is due to nonresponse. In

[2]This comparison has also been made by Costa et al. (2011) and Van Bavel (2014). Estimations based on the vital records were published by Sardon (1991).

fact, according to Van Bavel (2014) there is no reason to believe that non-respondent women had a particular fertility behaviour and missing values would not produce a substantial bias on fertility estimates.

The effects of migration may also be ruled out. One would expect migration to be positively correlated to fertility, i.e. women with less children would be more likely to out-migrate than those with large families. Out-migration would lead to an overestimation of fertility, not an underestimation.

Mortality would produce underestimated fertility numbers if high parity women had lower life expectancy than low parity women. However, this does not seem to be the case. As pointed out by Van Bavel (2014, p. 936), empirical studies do not indicate a positive correlation between fertility and mortality, especially not for old populations (Dribe, 2004; Gagnon et al., 2009).

Misreporting, on the other hand, is very likely to be high among the older cohorts for two reasons. First, one could expect memory gaps to be more frequent among elderly women compared to the younger cohorts. Second, as infant mortality was higher in the past, it is plausible that the number of unreported live children dead at young ages is higher among older cohorts.

In summary, data from the 1981 Census can be used to reconstruct the fertility behaviour of the birth cohorts whose reproductive life unfolded during the latter part of the fertility transition. However, it is important to keep in mind that the data underestimate fertility levels of these birth cohorts by at least 4%. Most probably, many births were not reported in the census by older women, due either to memory gaps or to the omission of infant deaths.

Either way, the focus of this research is not fertility in itself but diffusion processes. Even if fertility levels are underestimated, the data will still be useful to investigate the timing of adoption of modern fertility by these birth cohorts, according to their location in space and their education level.

4.1.2. Education level of older birth cohorts

Nonresponse, misreporting, mortality and migration can not only affect the overall fertility estimates but they can also bias the fertility differences among education levels (Van Bavel, 2014). In fact, these factors might be associated with specific fertility behaviour within educational groups. For example, highly educated women with low parity could be more likely to out-migrate; or high-parity women with low education could be more likely to misreport their number of births. If this is the case then fertility differences by education level will be not accurately estimated. In order to avoid misinterpretation Van Bavel (2014) suggests to only consider as significant the differences in fertility between education levels that are higher than 4%, i.e. above the general bias of fertility level in the census data.

In his analysis of fertility by educational gradient in the twentieth century, Van Bavel

(2014) classifies women from the 1981 Census within three educational groups: 'lower secondary at most', 'higher secondary completed' and 'tertiary education completed'. However, women from older birth cohorts are rather homogeneous in respect to their education level. The great majority of the women born between 1890 and 1899 reached primary education only and very few reached tertiary education. For this reason, in the individual analyses in this thesis the women are divided in two groups:

- Low education: maximum primary level;
- Medium/high education: secondary and higher.

4.1.3. Fertility and space in a retrospective approach

This research adopts a spatial-temporal perspective for the study of diffusion effects in the fertility transition. There is very little interest, for our purposes, to consider the overall fertility decline by education levels for the country as a whole. The use of the census micro data in the analyses will only make sense if we can situate individuals' fertility behaviour in space.

The 1981 Census contains a limited number of items about migration histories. The only relevant pieces of information are the following:

- municipality of residence in 1981;
- year at which each women moved to her dwelling of residence in 1981;
- municipality of birth.

With this limited information it is impossible to know for sure where each women lived during their reproductive life. It is likely that a considerable share of women moved several times during their lives and had children in places others than their municipality of birth or their municipality of residence in 1981.

There is only one group of women for whom we are sure of the place where they lived during their reproductive years: those who lived in the same dwelling since the birth of the first child until the census date. In other words, the only solution for a spatial analysis is to select the married women who did not move after the first child was born and had all their children in the same municipality where they were living in 1981. Of course, the fertility behaviour of these women is probably not representative of the fertility behaviour of their municipality. But, once again, the idea here is not to estimate fertility levels but to investigate diffusion mechanisms.

In summary, although we can reconstruct women's reproductive histories with the census data, we cannot be sure of where their reproductive histories took place. The only women whose reproductive histories can be located in space are those who have lived in the same dwelling since the birth of their first child until 1981.

4.2. Data selection from the 1981 Census

The data selection from the 1981 Census was carried out in two steps. The motivation behind the use of micro-level data in this thesis is to investigate individuals' adoption of modern fertility behaviour – that is, deliberate fertility control within the marriage – during the latter part of the fertility transition. Therefore, the first step was to select the women with the following characteristics:

- born between 1890 and 1899, thus with reproductive life unfolding during the latter part of the fertility transition, roughly between 1910 and 1940;
- with complete marriage, which allows to assume that a stopping in childbearing during the reproductive life would be deliberate, and not due to widowing or divorce;
- born in Belgium and having the Belgian nationality, in order to control for women's origin;
- with at least one child and legitimate births only;
- not living in the East Cantons, which were annexed to Belgium in 1920 and are not included in the aggregate dataset.

After this first selection we are left with 47,979 women from the 1981 Census.

In a second step I identified, among these women, those whose reproductive histories can be located in space, i.e. those who lived in the same dwelling since the birth of the first child until 1981. These women, who amount to 7,440, were the only ones included in the individual dataset, whereas the other 40,539 for whom the place of childbearing is uncertain had to be excluded. Table 4.1 compares several characteristics of the women included and excluded from the analysis.

Overall, the fertility behaviour of the two groups of women are very similar. The women included in the dataset have a slightly older fertility schedule. On average they were married later (26 years old against 24.5 for the excluded women) and the time span of their reproductive life course was delayed by around two years in respect to the others. On the other hand, the average inter-birth intervals and the total cohort fertility are very close in the two groups. The total fertility is higher by 0.1 for the included women.

The selected women are slightly less educated than the excluded ones, with 3% more women with low education level. Moreover, both groups display the same fertility profile by education. Educated women have a somewhat lower fertility, even though the difference might be considered as nonsignificant (around 4%; see subsection 4.1.2).

What really distinguishes both groups of women is their migration patterns. As one could expect, the included women – those who lived in the same dwelling for most of their lives – are much less mobile. In fact, 70% of them lived all their lives in their municipality of birth (against 44% for the excluded women).

Finally, the spatial distribution of both groups also present some differences. The included women are underrepresented in Brussels and in the province of Antwerp,

Table 4.1.: Women from the 1981 Census born between 1890 and 1899, with complete marriage and at least on child: comparison between those included and excluded from the dataset

	Included	Excluded
Number of women	7,440	40,539
Mean age at marriage	25.98	24.50
Mean age at birth of first child	28.49	26.43
Mean age at birth of last child	33.79	31.92
Average inter-birth interval	2.39	2.60
Education (%)		
Low	89.4	86.1
Medium / High	10.6	13.9
Cohort fertility		
All women	2.77	2.66
Low education	2.79	2.68
Medium / High education	2.64	2.57
Spatial mobility (%)		
Natives	68.1	44.4
Non-natives	31.9	55.6
Province of residence in 1981 (%)		
Antwerp	9.0	17.0
Brussels	2.8	10.3
Flemish Brabant	11.2	8.5
Walloon Brabant	3.1	2.5
West Flanders	12.5	11.9
East Flanders	17.3	14.9
Hainaut	17.2	14.6
Liege	9.6	10.1
Limburg	4.9	3.9
Luxembourg	5.6	1.9
Namur	6.7	4.4

Source: 1981 Population Census

whereas they are relatively overrepresented in the province of Luxembourg.

In summary, among the 47,979 women from the 1981 census that correspond to the general criteria of the analyses (Belgians born in Belgium between 1890 and 1899, with complete marriage and at least one child), only 7,440 could be located in space during their childbearing years. Only these women can be analysed from a spatial perspective and be linked to the macro-level indicators from the aggregate dataset. The brief analysis in this section suggests that the these women do not display a particular fertility behaviour compared to the others, although their spatial mobility is much more limited. Either way, it is important to keep in mind that the individual dataset is highly selected and might not be representative of all women present in the 1981 Census.

4.3. Individual dataset: overview

The discussion in section 4.1 pointed out two main problems of the 1981 Census data in respect to our aims. First, fertility levels of older birth cohorts are underestimated. Second, it is not possible to situate all the women's reproductive life in space.

The first problem does not entail a major limitation for the purposes of this thesis. In fact, the aggregate dataset already contains fine estimations of fertility levels during the whole fertility transition. The micro data will be used to investigate not fertility in itself but the role of diffusion effects on individual reproductive choices. Even if fertility levels are not estimated accurately, we may still be able to find evidence of diffusion with the micro-level data.

The second problem has more limiting consequences. Information on migration histories contained in the census is poor. In order to locate reproductive histories in space we have to constrain the analysis to the women who had been living in the same dwelling since the birth of their first child until 1981, which are the only women for whom we are sure of where their reproductive life took place. As a result, we are compelled to work with a selected population, whose reproductive behaviour may not be representative of all women.

To summarise, the individual dataset extracted from the 1981 Census is composed of 7,440 Belgian women born between 1890 and 1899. It includes complete marriages and at least one child, who have lived in the same dwelling since the birth of their first child until the census date. For these women we have information on education level, year of birth, year of marriage, municipality of origin, municipality of residence and the year of birth of each child. Because we can locate these women in space the individual dataset can be linked to the macro-level indicators of the aggregate dataset, in a multilevel perspective.

Despite its limitations the individual dataset offers many possibilities for the analysis of diffusion mechanisms. It allows the ability to test whether diffusion effects are stronger among highly educated women; or whether migrant women born in early-transition places are more likely to adopt modern fertility than the other women living in the same municipality. The specific use of the micro data is discussed in chapter 8.

Chapter 5.

Review of methods

The datasets gathered for this thesis make the most of the sources available in Belgium so as to operationalise the key elements of the research aims and hypotheses. Together, they contain individual and aggregate information on *fertility behaviour* and on different *cultural* and *structural* aspects of the population available at a *fine spatial and temporal level*, covering the *entire Belgian territory* throughout a *long period of time*.

The next step is to evaluate the different possibilities to use the data in order to:

- describe the spatial-temporal patterns of fertility decline;
- measure the importance of diffusion effects in the process of fertility transition, controlling for cultural and structural changes in space and time;
- investigate mechanisms of diffusion – in particular the role of spatial mobility and education – in the spread of modern fertility.

In other words, the question that this chapter will address is: what are the methods that best exploit the richness of the datasets in order to attain our aims?

The next section presents a brief review of the methods used in different fields to analyse diffusion. Drawing on this review, I discuss in section 5.2 the methods that are best suited for our particular aims given the nature of our data, and I introduce the analyses that will be carried out in the next chapters.

5.1. Quantitative methods to detect diffusion effects

Quantitative methods for the study of diffusion have been employed in different fields. Epidemiologists have developed many tools to analyse the transmission of contagious diseases and the clustering of other health-related problems, such as obesity and smoking (Marshall, 1991; VanderWeele, 2011). In criminology empirical studies have addressed the clustering of crime incidence in space and time (Grubesic and Mack, 2008; Johnson et al., 2007). Works in sociology have used diffusion models to explain the importance of social networks on collective movements and organisational structures (Palloni, 2001). In demography diffusion models have focused on reproductive behaviour – not only the limitation of births (see chapter 1, section 1.3) but also the choice of contraceptive methods (Kohler, 1997).

The basic idea of diffusion methods, in all these fields, is to assess how social interaction contributes to the increasing incidence of a given event within a population over time. Therefore, the methods must deal with two dimensions of the diffusion process: *time*[1] and *social interactions*.

Time is a natural component of diffusion studies. What motivates these studies is the process of change – the spread of a disease, the incidence of crime or a social transformation – that stretches over a given period of time. Consequently, the data and the methods must deal with the time interval during which a given event becomes increasingly prevalent within a population.

Social interaction, on the other hand, can be measured in different ways according to data availability and the purposes of the study. The most precise way to approach social interaction is using micro data on individuals' social networks, providing direct information on how and with whom individuals interact. Such detailed datasets are nonetheless seldom available. In this context, a spatial perspective is a powerful alternative to approach social interactions. As individuals tend to interact more with those who are near, spatial proximity is usually a good way to estimate the intensity of interactions between individuals. The spatial perspective can be applied to micro geocoded data or, more commonly, to aggregate data corresponding to spatial units. 'Proximity' between individuals or spatial units can be defined in different ways. For instance, in the case of aggregate data one could define proximity simply as the geographic distance between spatial units or even using more specific criteria, such as the intensity of migration flows or the transportation costs between units.

In summary, the purpose of diffusion methods is to integrate time and social interaction (or spatial proximity). Two main groups of methods can be distinguished in the literature. The first one consists of *statistic tools for space-time analysis*, which look for the clustering of events in space and time as evidence of diffusion. The second group builds on *causal diffusion models*, integrating time and social interaction (or space) into classic regression models.

5.1.1. Statistic tools for space-time analysis

Space-time analysis has been used in many studies with the aim of detecting diffusion effects. The premise is that the concentration of events in space and time would be

[1] There are some cross-sectional studies, namely on the diffusion of fertility control in the Southern United States (Tolnay, 1995) and on suicide in France and the United States (Baller and Richardson, 2002). However, because these studies lack a temporal dimension, they demonstrate the spatial concentration of social phenomena, rather than their diffusion.

indicative of a contagion process. Different tools have been developed in order to describe the spread of events in space and time and to provide direct measures of their spatial-temporal clustering.

A first, simple approach in space-time analysis is to observe the *evolution of the geography of a given indicator over time.* The idea is to test whether the spatial distribution of the indicator mimics contagion, that is, if it spreads gradually in space and time, from an innovation locus towards laggard regions. This can be done by the simple analysis of maps sequences in order to check whether the spread of an event in space and time is indicative of a contagion process. This was the method used in the works within the European Fertility Project (Coale and Watkins, 1986; Watkins, 1990) and it is commonly usewhetherd as a preliminary descriptive tool in many diffusion studies (Goldstein and Klüsener, 2014; Lesthaeghe and Neels, 2002; Montgomery and Casterline, 1993; Schmertmann et al., 2010).

A more rigorous option is to use spatial analysis tools to measure the *spatial clustering of an indicator over time.* In particular, the Moran's I statistic is a frequently used tool to measure the spatial clustering – or 'spatial autocorrelation' – of indicators (Baller and Richardson, 2002; Goldstein and Klüsener, 2014). The Moran's I of a given indicator is calculated as the correlation between each spatial unit and the mean value of its neighbouring units (Ward and Gleditsch, 2008). It measures therefore to what extent the indicator is concentrated in space. In a contagion process, one can expect that the evolution of the Moran's I value over time would have an inverted U-shape: in a first stage, the indicator of interest would be randomly distributed and spatial autocorrelation would be low; once the change begins in a leading area and spreads from there, the indicator would be increasingly clustered in space (the spatial autocorrelation would rise); at the end of the process, as the change is diffused everywhere, spatial autocorrelation would decline again.

Epidemiologists have developed more sophisticated tools to analyse the occurrence of diseases based on the principle that events that are close both in space and time are evidence of contagion (Pike and Smith, 1968). Rather than taking space and time separately, these tools focus on the *interaction between space and time.* A widely used method to test space-time interaction is the Knox test (Knox, 1964). Basically, this test compares pairs of events that are close both in space and time to a random distribution, if time and place of occurrence were independent[2] (Johnson et al., 2007). The Knox test has been used in epidemiological studies to investigate the outbreak and spread of infectious and non-infectious diseases (Birch et al., 2000; Jacquez, 1996; Samuelsson et al., 1994). In criminology the test has been used to identify 'hot spots' of crime, such as the concentration of criminal occurrences in given areas in a given interval of

[2]Many methodological works have proposed improvements of the original Knox test, as well as alternative tests based on the same principle – see Jacquez (1996), Kulldorff and Hjalmars (1999) and Marshall (1991).

time (Grubesic and Mack, 2008; Johnson et al., 2007). In demography, Bocquet-Appel and colleagues used the Knox test to estimate diffusion effects in the fertility transition in Britain (Bocquet-Appel and Jakobi, 1998) and in India (Bocquet-Appel et al., 2002). These studies attempt to test whether the onset of fertility decline are clustered in space and time, which would be an indication of a contagion process of birth limitations.

However, serious doubt has been cast on the power of space-time analysis tools as evidence for diffusion in the context of fertility change. Unlike the spread of diseases and crime, which occur within short intervals of time, social changes such as fertility decline are long processes. This implies that the factors affecting the risks of events across areas, such as age structures and socioeconomic conditions, may change over time (Kulldorff and Hjalmars, 1999; Schmertmann et al., 2010). For example, as marital fertility is related to the age structure and the nuptiality schedule of populations, changes in these factors may alter the geographic distribution of fertility over time without real behavioural change. Likewise, space-time interaction in fertility change may be due to the space-time clustering of cultural or structural factors that affect fertility and not to diffusion effects. As a consequence, in order to measure diffusion effects of a given social event it is essential to control for the spatial-temporal patterns of all the factors that are likely to affect the event. As pointed out by Schmertmann et al. (2010, p. 631), 'space-time interaction in demographic events is evidence of contagion only if it is unexplained by the space-time patterns in other relevant variables'[3].

In summary, tools for space-time analysis offer interesting ways to understand the spatial-temporal patterns of a given event. However, they are ill-suited for the study of diffusion in the context of fertility decline, which stretches over long periods of time. Therefore, these tools can be used to describe the spatial-temporal patterns of fertility change, but not as ultimate evidence of diffusion effects.

5.1.2. Causal diffusion models

A more comprehensive approach of diffusion, suited for social phenomena, integrates social interaction and a temporal dimension within classic causal models. A first formal formulation of such *causal diffusion models* was proposed by Erbring and Young (1979) and has served as an overarching framework for diffusion studies in sociology and in demography. A very simple representation of such models is given by the following equation[4] (Casterline, 2001):

$$Y_{it} = \beta X_{it} + \alpha \sum Y_{jt-1} W_j + \varepsilon_{it} \tag{5.1}$$

[3] In an attempt to correct this problem, Schmertmann et al. (2010) propose an alternative formulation of the Knox test that integrates Cox proportional hazards models in order to control for cultural, demographic and socioeconomic change over time – see chapter 1, section 1.3.

[4] This general equation is also mentioned in chapter 1, section 1.2.

This equation can be interpreted either from an individual or spatial (aggregate) perspective. Y_{it} expresses the dependent variable of interest at time t for individual i or spatial unit i. The right-hand side of the equation has two main components (other than the error term ε_{it}). X_{it} represents the set of relevant variables that are expected to influence the dependent variable. The second component – $\alpha \sum Y_{jt-1} W_j$ – accounts for the diffusion effect, endogenous feedback (Erbring and Young, 1979) or contagion effect (Montgomery and Casterline, 1993; Rosero-Bixby and Casterline, 1994). In an individual context, this term represents the behaviour Y of individuals j at time $t-1$, weighted by their relevance in the social network (W_j) of individual i. In the case of spatial units, the term expresses the value of indicator Y at time $t-1$ at spatial units j, weighted by their proximity to spatial unit i. The estimated value of α represents the importance of diffusion effects on the dependent variable, net of other relevant variables.

In summary, the equation illustrates a general causal model that integrates diffusion effects. The contagion term takes into account the two basic dimension of diffusion: time and social interaction (or spatial proximity). Furthermore, the diffusion effect is isolated from all the other covariates that are likely to influence the independent variable. In this sense, the model goes beyond the simple space-time statistic tools and it offers a more appropriate framework for the study of diffusion in the context of social changes.

The equation described above is a general formulation of a causal diffusion model. Of course, the specification and the estimation strategy of the model vary from one study to the other, according to the aims and the type of data. Still, there are basically two approaches to construct causal diffusion models: panel models and event-history models.

Panel models have been used in the study of diffusion effects in fertility transition in France (Murphy, 2015), Prussia (Goldstein and Klüsener, 2014), Taiwan (Montgomery and Casterline, 1993) and Costa Rica (Rosero-Bixby and Casterline, 1994) (see chapter 1, section 1.3). All these studies used pooled cross-sectional aggregate data containing several variables for spatial units at different points in time. Their results point to the important role played by diffusion in the fertility change.

Event-history models are often preferred in the context of micro studies of diffusion, using longitudinal data. The studies on the fertility transition in Belgium (Matthys, 2013; Van Bavel, 2004a) and the Netherlands (Bras, 2014) managed to integrate information on individual's networks into longitudinal datasets, and estimate the role of social interaction on fertility decisions. The advantage of individual approaches is that not only do they give more direct evidence of diffusion, but they also elucidate mechanisms of diffusion. For example, Bras (2014) and Van Bavel (2004a) found that modern fertility behaviour is more likely to be diffused within heterogeneous networks. In particular, their results suggest that migrants coming from pioneering places in the fertility transition were likely to influence reproductive behaviour of native couples.

Event-history models can also been used in the context of spatial analyses of diffusion. Hedström (1994) built an event-history model to investigate the diffusion of trade unions in Sweden between 1890 and 1940 at the district level. His dataset contained yearly information on the formation of trade unions in districts, as well as districts' demographic information at census years. His model estimates the conditional probability that a first association is formed at district i at time t, as a function of the the number of union members in other districts j at time $t-1$ weighted by the districts distance and controlling for demographic factors that are likely to be related to union formation. The results suggest that a spatial contagion process was at play in the growth of union movements in Sweden. This 'spatial longitudinal' approach offers a more dynamic view of the diffusion process compared to panel models.

Ultimately, the choice of the estimation method – panel or event-history – depends on the characteristics of the data. However, event-history models are better suited for the analysis of the temporal dimension of diffusion. Whereas panel models take only discrete observations in time, event-history models use detailed sequences of events, which allows to capture the dynamics within the diffusion process. In fact, as Strang (1991) argues, the dynamic nature of event-history models offer a natural framework for the study of diffusion.

5.2. Choices of methods and analyses

With the data gathered for this thesis, it is possible to apply many of the methods discussed above.

The aggregate data is well-suited for fine spatial-temporal analyses of the Belgian fertility transition. The key variable for this study – the marital fertility index I_g – is available year by year, at the level of the municipalities. Most of the structural and cultural indicators are available for census years, either at the level of the municipalities or districts. The aggregate dataset offers therefore a high level of spatial and temporal detail and covers all the relevant factors that are likely to influence the course of the fertility transition. *Tools for space-time analysis* can be applied to this dataset in order to produce a detailed description of the spread of fertility decline in Belgium. Moreover, the dataset can be used to construct a *macro-level causal diffusion model*, taking into account the dynamics of the fertility transition and measuring diffusion effects, net from structural and cultural changes.

The individual dataset has two main problems. First, it is composed of a selection of women, and it is thus not representative of the overall reproductive behaviour (see chapter 4). Second, it does not contain direct information on individuals' networks. Still, with these data, it is possible to look into some mechanisms of diffusion, namely the role of spatial mobility and education on the spread of modern fertility. In particular, the individual data can be linked to the aggregate indicators in a multilevel perspective, which allows to investigate the interactions between individual behaviour and its macro/spatial determinants. The dataset can thus be used in a *multilevel causal diffusion model* to detect contagion effects on individual behaviour and to elucidate mechanisms of diffusion.

Three complementary quantitative analyses will be carried out in the next chapters. The first one is a descriptive analysis using several space-time analysis tools, namely the observation of maps sequences, the study of the spatial clustering of fertility over time using the Moran's I, and the investigation of space-time clustering though the Knox test. Next, two causal diffusion models are built on event-history frameworks – from a macro- and from a multilevel perspective. These three complementary analyses exploit the richness of the datasets in order to search for diffusion effects and investigate diffusion mechanisms in the Belgian fertility transition.

Part III.

Analyses

Chapter 6.

Descriptive spatial-temporal analysis

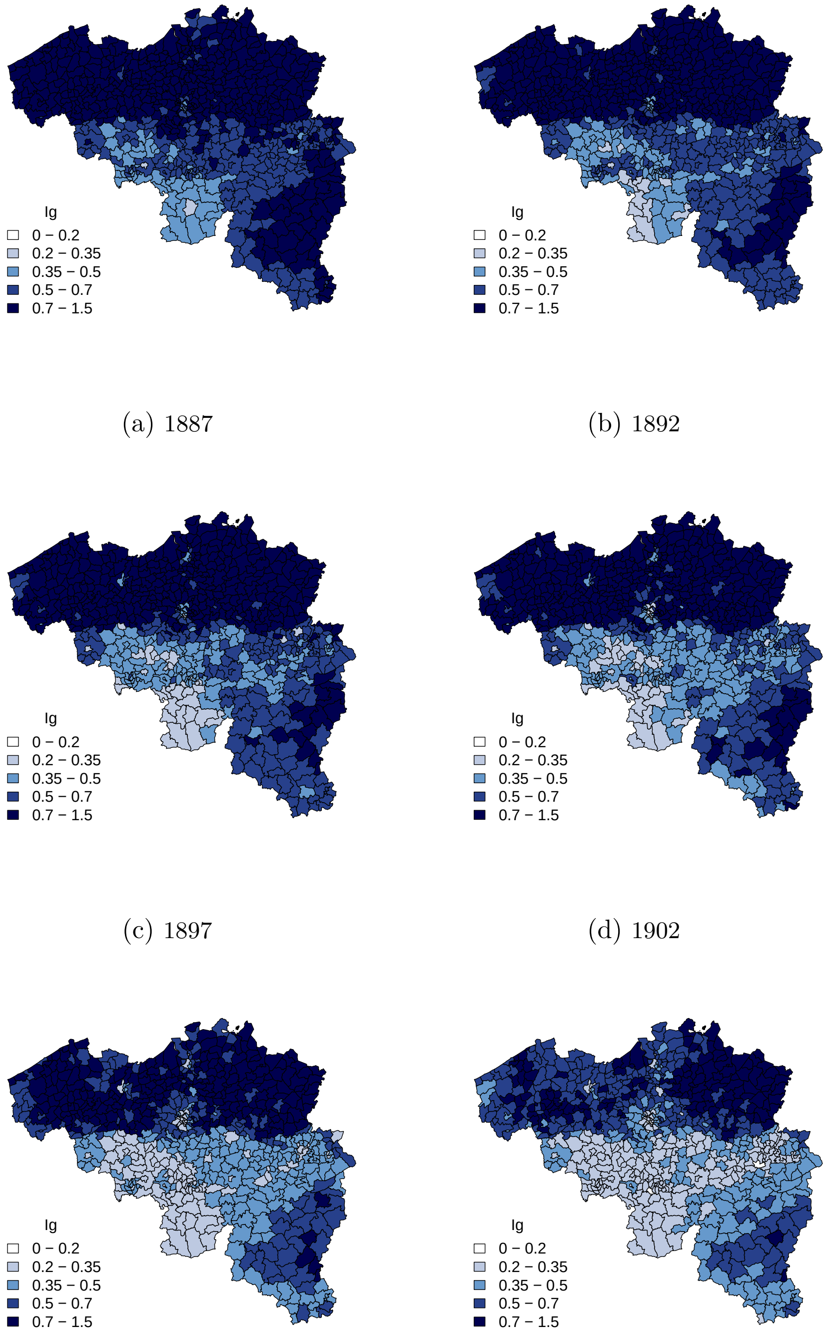
The purpose of this chapter is to investigate the spatial-temporal patterns of fertility decline in Belgium. Different methods are applied in order to describe the geography, the timing and the pace of the Belgian fertility transition, as well as to look for the first evidences of diffusion effects. The analyses carried out in this chapter are based on the annual series of the marital fertility index I_g, calculated between 1887 and 1934 at the municipal level (see chapter 3).

In section 6.1, the I_g time series is used to construct a maps sequence, offering a first outlook of the transition process. The map sequence provides a detailed picture of the path of fertility decline across the Belgian territory. Section 6.2 proposes specific criteria in order to identify the year of onset of fertility decline for each municipality in the dataset. With this information I analyse the timing and the pace of the transition process. Finally, in section 6.3 I use different statistical tools to obtain objective measures of the spatial and temporal clustering of fertility change during the transition.

6.1. The geography of fertility decline

The first use of the I_g annual series was to produce a map sequence illustrating the distribution of marital fertility levels of municipalities between 1887 and 1934. The map sequence offers a first overview of the spatial-temporal patterns of fertility decline in Belgium. Figures 6.1 and 6.2 respectively present six and four maps before and after the First World War.

All the maps were produced using the same categories of I_g. Fertility control is likely to be absent in areas displaying I_g levels above 0.7 (depicted in dark blue) and municipalities in this category can thus be considered as pre-transitional (Lesthaeghe, 1977). The observation of the maps sequence gives a first idea of how fertility decline occurred in space and time, with a fine level of geographic detail.



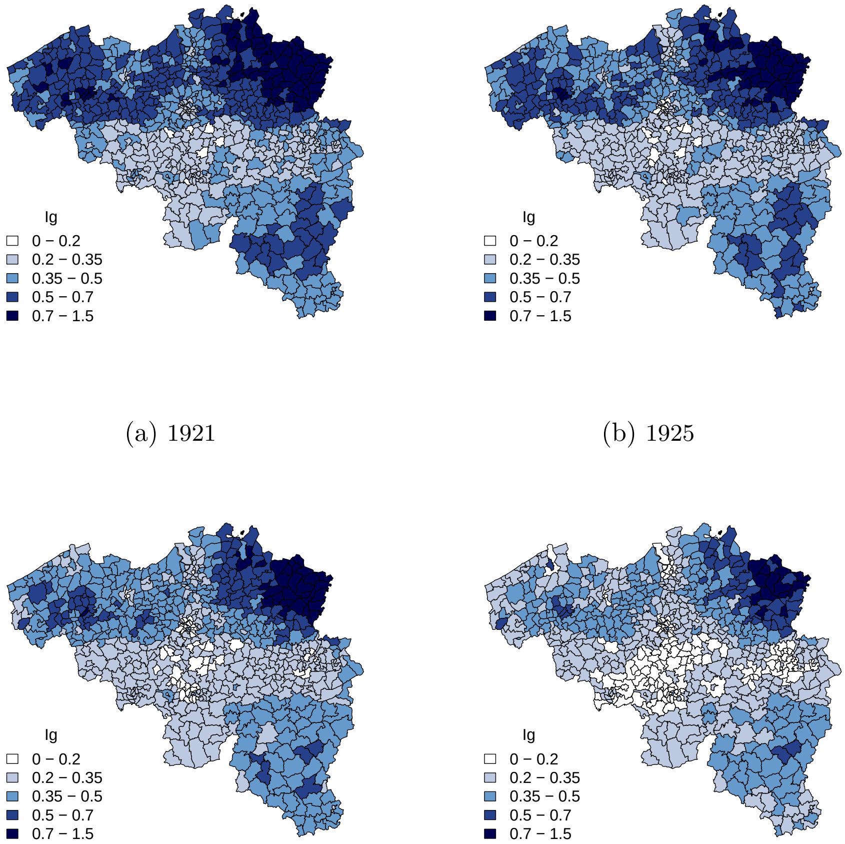
(a) 1887 (b) 1892

(c) 1897 (d) 1902

(e) 1907 (f) 1912

Sources: *Mouvement de la population et de l'état civil* and Population Censuses

Figure 6.1.: Municipal distribution of the marital fertility index (I_g) 1887–1913



(a) 1921

(b) 1925

(c) 1930

(d) 1934

Sources: *Mouvement de la population et de l'état civil* and Population Censuses

Figure 6.2.: Municipal distribution of the marital fertility index (I_g) 1921–1934

At the beginning of the observation period (1887), a considerable number of municipalities had not yet started their fertility transition ($I_g > 0.7$). These pre-transitional municipalities are mostly situated in the Dutch-speaking part of Belgium, as well as in the Ardennes (south-east). The lowest levels of marital fertility were found within a layer of municipalities in the provinces of Hainaut and Namur (south-west), stretching along the French border. This early-transition zone had an I_g level already below 0.5 in 1887 and was composed of both industrial and rural areas.

From the 1890s until the early twentieth century fertility transition gradually spread from the early-transition area in Hainaut and Namur to the rest of Wallonia, along the industrial axis Charleroi-Namur-Liège, rapidly attaining low levels ($I_g < 0.35$). During this period marital fertility also started to decline in Brussels and adjoining municipalities and in the Flemish major urban areas – Antwerp and Ghent. Interestingly, Flemish municipalities situated at French border also experienced some fertility decline during this period, much earlier that the rest of Flanders. Fertility also began to fall in the Ardennes, whereas at a slower rates. In fact, the Ardennes had persistently higher fertility level compared to the rest of Wallonia throughout the whole period.

The linguistic border seems to have played an important barrier effect on the spread of fertility decline, even at the municipal level. Indeed, there is a clear distinction of fertility levels between the two main linguistic regions throughout the entire period. With the exception of the major cities nearly all the Flemish municipalities experienced a very late decline compared to Wallonia. Most Dutch-speaking municipalities situated at the linguistic border displayed pre-transitional fertility levels until the first decade of the twentieth century, whereas their French-speaking neighbours were already in an advanced stage of the fertility transition, with I_g levels lower than 0.5.

It was not until the 1910s that fertility decline began to penetrate in Flanders. It occurred along two main axes: Brussels-Antwerp and Brussels-Ghent-Bruges. From there, it later spread to the rest of the Dutch-speaking municipalities, especially after First World War. Municipalities in the province of Limburg (north-east) were true latecomers of the fertility transition. In 1934, the signs of fertility decline were hardly starting to appear, whereas fertility level was already quite low everywhere else in Belgium.

The general spatial-temporal patterns described here are consistent with those found by Lesthaeghe (1977) using observations at the arrondissement level with ten-year intervals. However, the annual observations at the municipal level offer a much more detailed picture of the Belgian fertility transition. In particular, three points stand out from the maps sequence.

First of all, the propagation of fertility decline showed by the maps follows a strikingly contiguous path. The fall in I_g values spreads gradually among neighbouring areas, year after year, first within Wallonia and later into the north of the linguistic border.

Second, this gradual spread first took place along the industrial and urban axes in Wallonia and in Flanders, following the main transportation networks (Laffut, 1998).

In contrast, fertility decline was delayed in areas that were less connected to the industrial/urban axes in Belgium, such as the Ardennes in Wallonia and the Limburg province in Flanders.

Finally, national and linguistic borders seem to have played an important role in the spatial-temporal patterns of fertility decline. On the one hand, the proximity to the French border is associated with an earlier transition. All the Walloon municipalities situated at the French border – rural and urban – had I_g values below 0.7 in 1887, indicating their early fertility transition. Dutch-speaking municipalities at the French border also experienced an earlier decline compared to the rest of Flanders. On the other hand, the linguistic border in Belgium seems to have delayed the spread of modern fertility behaviour from Wallonia to Flanders and it appears as a clear divide of marital fertility levels throughout the first part of the twentieth century.

6.2. The timing and pace of fertility decline

The maps sequence presented in section 6.1 offers a dynamic outlook of the geography of fertility decline in Belgium. However, the relatively loose analysis of municipal fertility levels over the years does not yield objective conclusions about the timing and the pace of the fertility transition. On the one hand, the maps sequence contains too much information and, on the other hand, the broad categories of I_g used in the maps could mislead the interpretation of the course of the transition. In order to better understand the spatial-temporal patterns of fertility decline we need objective criteria to determine exactly when the decline started in each municipality. With these criteria, the timing and the pace of fertility decline can be analysed in a more precise way.

6.2.1. Definition of the year of onset of fertility decline

The year of onset of fertility decline has to be defined for each one of the 645 municipalities, based on the annual series of I_g calculated between 1887 and 1934. However, a problem with the I_g time series is that index values are missing for the First World War years. As mentioned in chapter 3, the *Mouvement* data series was broken between 1914 and 1918. Municipal data available for that period is incomplete. Moreover, data quality in 1919, just after the war, seems to be poor. In order to complete the annual fertility series a linear interpolation of I_g was operated for each municipality between 1914 and 1919. Of course, this strategy produces a rough approximation of fertility levels during the war years. As a matter of fact, it is known that fertility levels were disrupted during the War, with a rapid decline followed by a recuperation in the post-war years (Eggerickx, 2014; Eggerickx et al., 2014). However, as it will be made clear below, the linear interpolation does not have a major impact on the definition of transition years.

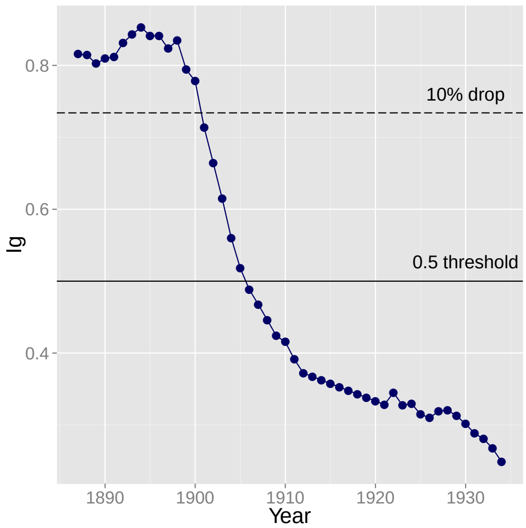
There are basically two ways of determining the year of onset of fertility decline. A common approach is to consider the year in which I_g dropped by 10% of its pre-transitional level and did not rise above this point afterwards. This definition was first proposed in the European Fertility Project (Coale and Watkins, 1986, app. D) and has been traditionally used in studies about the fertility transition. Alternatively, a second way to determine the time of transition onset is simply to take the year in which the fertility level fell under a certain threshold. In this thesis tests were made using both approaches.

For the first approach – '10% drop rule' – it was first necessary to identify the municipalities which had already started their fertility transition prior to the beginning of the time series. Following Lesthaeghe (1977, p. 92) I consider that an I_g value above 0.7 indicates no fertility control. In other words, the municipalities whose I_g value in 1887 was below 0.7 and did not rise above this threshold in the following years are considered to have started their transition at an unknown year before 1887 (they are defined here as 'non-eligible'). For all the other municipalities the I_g value in 1887 is taken as a reference. The year of onset of fertility transition is then defined as the first year in which I_g permanently fell below 90% of the reference value.

The definition of transition years based on thresholds is straightforward. Tests were made for different thresholds, ranging from 0.7 to 0.5. Higher thresholds showed a very similar profile to the 10% drop approach. For this reason the 0.5 threshold was preferred. In contrast to the 10% drop rule, which indicates the 'outbreak' of fertility decline, the 0.5 threshold rule refers to an advanced stage of the transition in which the decline process is well underway. For each municipality's time series I took the year in which I_g permanently fell below the 0.5 threshold. Again, municipalities whose maximum I_g level was lower than 0.5 over the whole period are non-eligible: they have an unknown transition year prior to 1887.

Figure 6.3 illustrates the I_g time series of the municipality of Ronse, a mid-sized Flemish town located at the linguistic border. Marital fertility level fluctuated around 0.8 before 1900, when it finally started to fall. For the 10% drop approach, the 1887 reference level for Ronse is $I_g = 0.82$. The year of onset of fertility transition is the first year in which I_g fell below 90% of the reference level, i.e. $I_g = 0.73$. This occurred in 1901, when I_g had dropped to 0.71 and fertility did not rise in the subsequent years. Thus, 1901 is considered to be the year of onset of fertility transition in Ronse by the 10% drop rule. Later on marital fertility continued to decline. It finally fell below the 0.5 threshold in 1906.

Table 6.1 shows the proportion of municipalities for which transition years are unknown or poorly estimated for both transition criteria. Transition years are unknown for municipalities whose transition occurred before 1888 (non-eligible) or after 1934 (right censoring) and are thus not observed in the time series. Transitions years between 1914 and 1919 are considered to be poorly estimated, as they fall within the interpolated period during the First World War years. The table distinguishes cities and towns in



Sources: *Mouvement de la population et de l'état civil* and Population Censuses

Figure 6.3.: Evolution of I_g in Ronse (1887–1934)

Flanders and Wallonia[1].

For the 10% drop rule, nearly one third of the municipalities experienced an early transition (non-eligible). These are mainly situated in Wallonia, which experienced an early onset of the fertility transition. In fact, the transition of 88.6% of cities and 66% of towns in Wallonia occurred prior to 1888. Most of the other municipalities experienced their onset of fertility decline during the observation period. At the end of the time series, in 1934, only four municipalities in Flanders had not yet started their fertility transition as defined by the 10% drop rule (right-censored). In contrast, the number of non-eligible municipalities is much smaller for the 0.5 threshold rule (8%). Nearly 20% of municipalities in Brussels and in Wallonia had already an I_g level below 0.5 in 1887. At the end of the time series, one-tenth of the municipalities had not yet cut across the 0.5 mark – mostly Flemish towns. Overall, unobserved transitions sum up to 33% for the 10% drop rule and to 18% for the 0.5 threshold criterion. Finally, only a small share of the municipalities experienced their onset of fertility decline during the war years: 9% for the 0.5 threshold rule and 3.3% for the 10% drop rule. Poorly estimated transitions concern mainly Flemish towns.

In summary, for each municipality of the dataset the fertility transition year was estimated using two separate approaches. The 10% drop rule conveys the very begin

[1] In the dataset 'cities' are defined as old municipalities with more than 10,000 inhabitants in 1900 – see chapter 3, section 3.2.

Table 6.1.: Unobserved and inaccurately observed transitions: proportion of non-eligible and right-censored municipalities and transitions during the First World War (%)

		Belgium	Brussels	Flanders		Wallonia	
				cities	towns	cities	towns
Non eligible	0.5 threshold	8.1	21.1	0.0	0.0	22.9	16.2
	10% drop	32.4	36.8	4.9	1.3	88.6	66.8
Right-censored	0.5 threshold	9.8	5.3	7.3	18.8	0.0	0.8
	10% drop	0.6	0.0	0.0	1.3	0.0	0.0
Transitions WWI	0.5 threshold	8.8	0.0	7.3	19.1	0.0	0.4
	10% drop	3.3	0.0	0.0	6.9	0.0	0.0
	N	645	19	41	303	35	247

of the fertility decline process. Because it takes into account the proportional fertility drop it does not entirely depend on the initial fertility level. The 0.5 threshold rule, on the other hand, corresponds to an advanced stage of the fertility transition. It refers to a specific level of the marital fertility index. Both approaches will be used throughout the different analyses in this thesis.

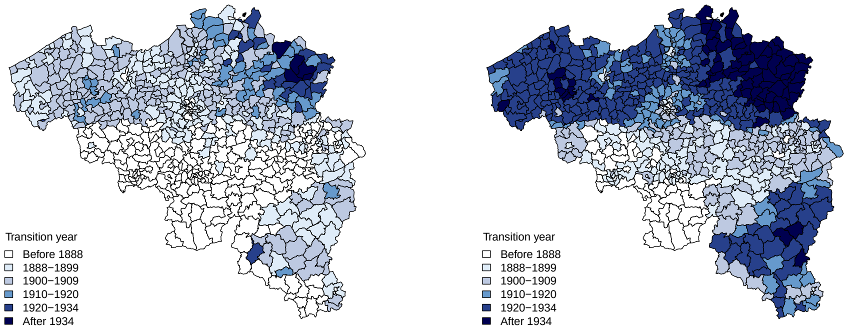
Despite its limitations – mainly due to censoring and the transitions during the First World War – the annual I_g time series used in this thesis allows to estimate the timing of transition onset of municipalities with a certain level of detail, especially compared to previous studies. In fact, most spatial studies of the transition use census data available every ten years. They can only produce a rough estimation of the time of onset of fertility decline. With the two criteria discussed in this subsection two crucial moments of the fertility transition are defined with much more temporal precision, year after year between 1888 and 1934.

6.2.2. The transition process

Based on the two transition criteria discussed above the timing and the pace of fertility decline can be assessed in a more objective way.

The two maps in figure 6.4 depict the spatial distribution of transition years for the two criteria. Compared to the maps sequence in figures 6.1 and 6.2 these new maps offer a more synthetic picture of the spatial-temporal patterns of fertility decline. The 10% drop rule map (6.4a) illustrates the moment of outbreak of fertility transition in each municipality. The 0.5 threshold rule map (6.4b), in contrast, represents a later moment of fertility decline, when each municipality had reached an advanced stage of the transition.

It is clear from figure 6.4 that the spatial distribution of transition years is very similar for both criteria, which indicates that both the onset and the pace of fertility



(a) 10% drop rule (b) 0.5 threshold rule

Sources: *Mouvement de la population et de l'état civil* and Population Censuses

Figure 6.4.: Municipalities' transition years according to the two transition criteria

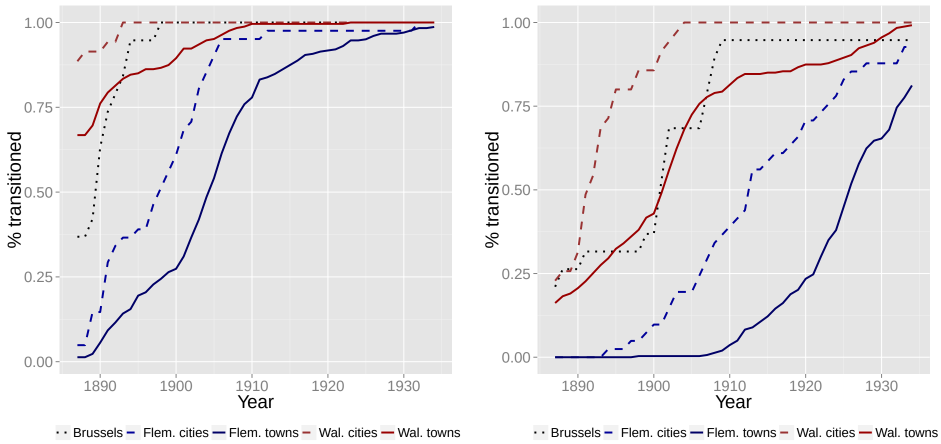
decline followed the same patterns. What is more, these maps show that the timing and pace of fertility transition are highly clustered in space and time. Municipalities that are close in space experienced their fertility transition within the same period of time.

Furthermore, what is also striking in both maps is the major differences in transition timing across the Belgian territory. Prior to 1888 many municipalities in Wallonia experienced an early start of fertility transition (non-eligible). The south of the provinces of Hainaut and Namur, close to the French border, had already attained the 0.5 threshold at that time. Conversely, five decades later, fertility was only starting to fall in some of the Flemish *communes* situated at the Dutch border, in the province of Limburg. These municipalities are clearly latecomers in the fertility process. By 1934, some of them had not yet started the decline and most of them of had not yet reached an advanced stage of the transition (right-censored).

The space-time distribution shown in the maps in figure 6.4 confirms the interpretations of the maps sequence in section 6.1. Wallonia had an early fertility decline, except for the Ardennes. In this rural, little densely populated zone in the south of Belgium fertility decline started around the turn of the twentieth century and progressed slowly, reaching the 0.5 threshold only after First World War. The northern part of Belgium experienced a much later transition compared to most French-speaking *communes*. Fertility first began to drop in Brussels, Antwerp and Ghent roughly at the same time and pace as in Wallonia, followed by their neighbouring municipalities. Later, fertility transition finally reached the rest of Flanders and at last the province of Limburg, which displayed persistently high fertility levels.

In summary, the broad picture suggested by the maps is that of a double contrast in the timing and pace of fertility transition in Belgium: a regional divide between the two linguistic regions, and a urban/rural divide, especially in Flanders.

Regional and urban/rural differences in the transition process are portrayed by the transition curves in figure 6.5. These curves represent the cumulate proportion of municipalities having attained the transition criteria (10% drop rule and 0.5 threshold rule) by year. They show the pace of fertility transition process of cities and towns in each one of the linguistic regions, as well as in the Brussels region.



(a) 10% drop rule

(b) 0.5 threshold rule

Sources: *Mouvement de la population et de l'état civil* and Population Censuses

Figure 6.5.: Fertility transition profiles by area according to the two transition criteria

Considering the 10% drop rule (figure 6.5a), Walloon cities had all started their fertility decline by the early 1890s, as well as a great share of Walloon towns. However, transition in Walloon towns progressed slowly between 1890 and 1910, which is due to the persistently higher fertility levels in the Ardennes. Flemish cities are characterised by a later but very rapid transition process, catching up with Wallonia around 1905. The latest group was the Flemish towns. Their transition process accelerated sharply between 1900 and 1910, as fertility control attained most of the Flemish *communes*. After 1910 the process was slowed down again by the latecomers municipalities in the Limburg province.

As there are less non-eligible municipalities for the 0.5 threshold criterion (figure 6.5b) the curves show a more complete picture of the transition process. The quick progression of Walloon cities, followed by Walloon towns and the municipalities in Brussels, contrasts with the much later fertility decline in Flanders. The graphic shows a stagnation of the transition process in Walloon towns after 1910, reflecting again the resistant high fertility levels in the Ardennes. By 1910, whereas a great share of French-speaking Belgium had already attained the 0.5 threshold, Flemish municipalities were still way behind.

Although we cannot observe entire transition processes in figure 6.5, it is still possible to notice that the transition curves have an S-shaped form, which is a typical outcome of diffusion (Hedström, 1994). In most diffusion processes the number of adopters of a given behaviour progresses slowly in the beginning; as contagion effects are set in motion the proportion of adopters quickly accelerates; in the end the process slows down again, when the resistant latecomers eventually become adopters too. The transition curves and the information in the maps in figure 6.4 are consistent with such process. After a group of leading municipalities start their fertility transition, the process quickly accelerates, with municipalities adopting modern fertility behaviour at an increasing rate. In the end the spread of the transition finally stalls when latecomer zones – such as the Ardennes and Limburg – seem to resist the adoption of modern fertility behaviour.

6.3. Spatial and temporal clustering in the fertility transition

The analyses in sections 6.1 and 6.2 suggest that the process of fertility decline in Belgium was highly clustered in space and time. This could be a sign that diffusion effects were at play during the fertility transition. At this point it is relevant to test the spatial and temporal clustering of fertility using statistic tools for space-time analysis. Their purpose is to measure to what extent municipalities that are close in space tend to experience fertility transition at the same period of time.

In this section two different analyses are carried out. Firstly, I use spatial analysis tools to assess the evolution of spatial clustering over time. Secondly, I employ the Knox test, which takes space and time together in order to test the importance of the space-time interaction in the marital fertility time series.

A preliminary step in spatial analysis relates to the definition of spatial proximity between spatial units. In our case proximity is supposed to reflect the intensity of social interaction between municipalities. People who live close to each other are expected to interact more; as a consequence, if a contagion process of fertility decline exists then modern fertility behaviour will spread among places that are close in space.

There are different ways of dealing with spatial proximity. Obviously, a simple approach is to use the geographic distance between municipalities. Nonetheless, other specific criteria can also be used, such as the transportation costs or the migration flows between units. However, such criteria could not be applied to our case for lack of appropriate data. Moreover, parameters such as migration flows and transportation costs are likely to change over time. It is important to define a constant measure of proximity throughout the whole period covered by our data.

I use a straightforward approach of spatial proximity based on the contiguity between spatial units. Two municipalities are considered to be close in space – or 'neighbours' – if they share a common border, no matter its extension. This information was constructed in the form of a binary matrix containing all pairs of municipalities; each case of the matrix has value 1 if municipalities are neighbours, and 0 otherwise.

6.3.1. Tests for spatial clustering

A simple way to assess the spatial clustering in the data is to compare the indicator value for each spatial unit with the mean value in its surroundings, or the 'spatial lag'. In our case the idea is to compare the I_g level of each municipality with the mean I_g value of its neighbours, i.e. the lagged I_g[2].

The scatterplots in figure 6.6 compare the I_g of each municipality with its lagged I_g in 1887 and 1934. The positive association between the two measures indicate that marital fertility was highly clustered in space: municipalities with high I_g levels have high-fertility neighbours; conversely, low-fertility *communes* tend to have low-fertility neighbours. In 1911 (figure 6.6a) we can clearly distinguish the Flemish municipalities with higher levels of I_g compared to Wallonia. Flemish points were also more dispersed in the earlier phase of the fertility transition. As fertility transition progresses (figure 6.6b) Flemish locales come closer to the Walloon ones at lower I_g levels and the positive relation becomes stronger.

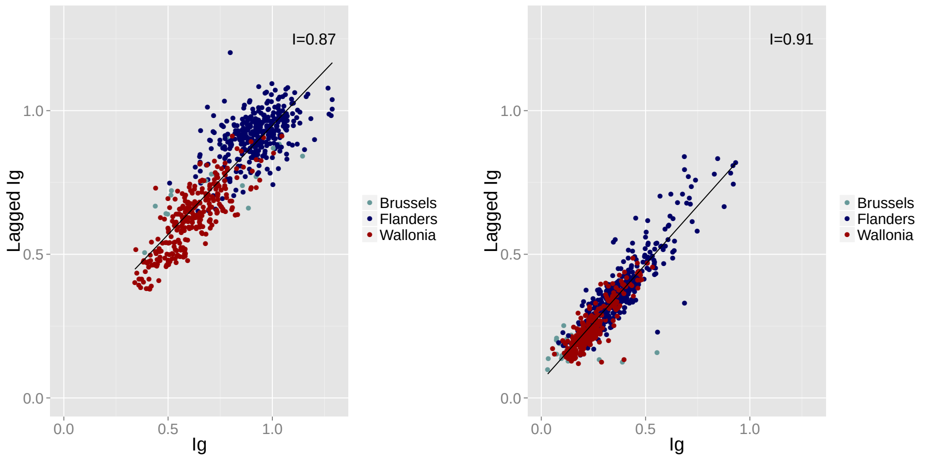
The correlation between I_g and its spatial lag (indicated in figure 6.6 by the slopes of the linear regression lines) offers a global measure of spatial association, known as the Moran's I statistic[3]. Its interpretation is similar to that of the Pearson correlation index, ranging between -1 and 1. $I = 0$ indicates no spatial association in the data, whereas positive values close to 1 suggest that the data is highly clustered in space, i.e. that spatial units resemble more their neighbours than all the spatial units taken together. The Moran's I value is very close to unit in the two years of observation represented in figure 6.6, which confirms the high spatial clustering of I_g in Belgium both in the beginning and in the end of the time series.

The Moran's I statistic was computed for each year of the I_g time series between 1887 and 1934 (figure 6.7). Spatial clustering was high in Belgium during the entire period, with a Moran's I value above 0.85 for each year.

In principle, in a typical transition process shaped by diffusion the evolution of the Moran's I statistic is expected to have an inverted U-shape. In the case of marital

[2] I use equal weights to compute spatial lags. For instance, if a municipality shares borders with three other ones each one of the neighbouring municipalities will have weight 1/3 in the calculation of the lagged I_g.

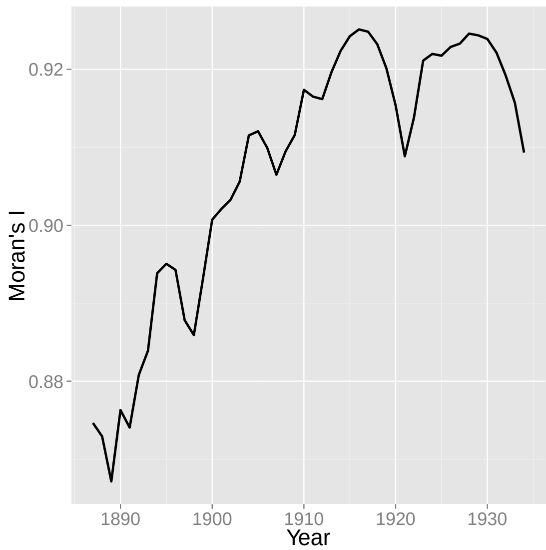
[3] For a formal explanation of the Moran's I, see Ward and Gleditsch (2008) and Oliveau (2010).



(a) 1887 (b) 1934

Sources: *Mouvement de la population et de l'état civil* and Population Censuses

Figure 6.6.: Spatial clustering: plot of municipalities' I_g against their spatial lags



Sources: *Mouvement de la population et de l'état civil* and Population Censuses

Figure 6.7.: Evolution of the spatial clustering of marital fertility: Moran's I by year (1887–1934)

fertility spatial correlation would be low before the transition because fertility would be close to the natural level everywhere ($I_g \approx 1$). As modern fertility behaviour appears in a pioneering spot and diffuses from there, spatial association would become increasingly high. In the end of the process, when marital fertility would reach low levels across the whole territory, spatial correlation would fall again. The Moran's I sequence in figure 6.7 shows very high values throughout the entire period. Spatial association rose between the late nineteenth century and the First World War, and declined somewhat after that. Still, even though the curve is slightly inverted U-shaped, the Moran's I values have a small variation, ranging between 0.87 and 0.92 only.

There are two possible explanations for the absence of a clear inverted U-shape in the Moran's I evolution in the fertility time series. First, the time-span 1887–1934 is possibly too short and we do not observe the beginning of the transition process nor the eventual convergence of fertility levels in the end. Second, it could be that fertility levels in Belgium are persistently clustered in space because of regional particularities in fertility behaviour (Costa et al., 2011).

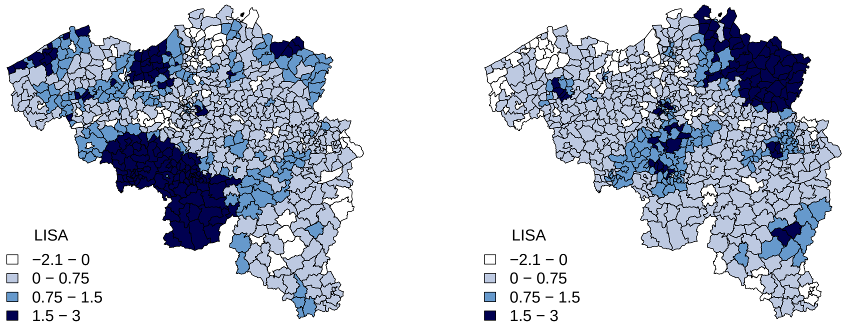
Finally, it is useful to consider the individual contributions of each municipality to the global Moran's I, known as Local Indicators of Spatial Association (LISA) (Anselin, 1995) or local Moran's I. This disaggregated measure expresses the degree of similarity of each spatial unit with its neighbours. It is obtained by the multiplication of the standardised z-scores of I_g of each municipality by its lagged z-scores (Ward and Gleditsch, 2008). Figure 6.8 brings the LISA maps for the first and last years of the I_g time series.

Two zones stand out in these maps: a group of municipalities in the south-east of Wallonia in 1887 and another group in the north-east of Flanders in 1934. These zones correspond, respectively, to the pioneers and the laggards of Belgium's fertility transition. They appear as homogeneous zones where fertility levels are particularly clustered in respect to the rest of the territory. In other words, the pioneering municipalities are the ones that most contributed to the high values of the Moran's I in the beginning of the time series, as did the laggard municipalities in the end.

This result seems to confirm that the persistently high spatial clustering between 1887 and 1934 is due to the fact that the time series does not cover the entire fertility transition in Belgium. If we could compile the Moran's I statistics before the onset of fertility decline in Wallonia and after the transition was completed in Flanders, we would probably observe lower pre- and post-transition levels of spatial association.

6.3.2. Tests for space-time clustering

The methods employed above dealt with space and time separately: the analysis consisted of assessing the spatial clustering of fertility year after year. In addition, these tools were based on the spatial distribution of fertility *levels* at each year, leaving out the notion of *timing and pace* of fertility decline. In this subsection I use the Knox



(a) 1887

(b) 1934

Sources: *Mouvement de la population et de l'état civil* and Population Censuses

Figure 6.8.: Municipalities' degree of similarity with their neighbours in terms of fertility level: LISA

test in order to evaluate to what extent the onset of fertility decline in Belgium was clustered both in space and in time.

The Knox test was originally employed by epidemiologists in order to test for space-time interaction in the outbreak of diseases (Knox, 1964; Marshall, 1991). The occurrence of diseases cases in geographically close locations at about the same time would be an evidence of infectious patterns (Schmertmann et al., 2010). Basically, the idea is to compare each possible pair of events in respect to their location and time of occurrence. The number of pairs of events that are close both in space and time is then tested against the null hypothesis that the place and time of events are randomly distributed. What is considered to be close in time and close in space is defined by the researcher according to the nature of the event of interest.

The Knox statistic is calculated as folows[4]. Consider n events, each of which with a known location and time of occurrence. In total, there are $N = n(n-1)/2$ possible pairs of events. Each pair is evaluated in respect to their closeness in space and in time, as defined by the researcher. The number of pairs of events that are close in time can be expressed by $N_t = \sum_i \sum_{j>i} \tau_{ij}$, with $\tau_{ij} = 1$ if events i and j are temporally close and 0 otherwise. Similarly, the number of pairs that are close in space is given

[4]The presentation of the Knox test in this subsection, as well as the notation, is based on Schmertmann et al. (2010). The Knox test is very well explained in their paper. For more details on the test, see also Knox (1964) and Marshall (1991).

by $N_s = \sum_i \sum_{j>i} \sigma_{ij}$, with $\sigma_{ij} = 1$ if events i and j are spatially close and 0 otherwise. Finally, the Knox statistics X accounts for the total number of pairs which are close both in space and in time:

$$X = \sum_i \sum_{j>i} \tau_{ij}\sigma_{ij} \tag{6.1}$$

In our case the event of interest is the fertility transition. The place of occurrence of each event is the municipality. The time of occurrence can be estimated by the two criteria discussed in subsection 6.2.1: the 10% drop rule and the 0.5 threshold rule. Two different tests were carried out, one for each transition criterion. I consider events to be *close in space* if they occurred in neighbouring municipalities. Moreover, transition cases are defined as *close in time* if they occurred within a five-year interval.

For the 10% drop rule there is a total of 432 observed transitions[5]. There are $N = 93,096$ possible pairs of events. Table 6.2 presents the distribution of these pairs according to their spatial and temporal proximity. 26,915 pairs of transitions were neither close in space nor in time. 64,023 pairs were close in time but not in space, whereas 1,553 pairs of transitions were close in space but fell out of the five-year interval. The Knox statistic is $X = 605$: this is the number of neighbouring municipalities that experienced their onset of fertility decline within a five-year interval.

Table 6.2.: Knox contingency table – 10% drop rule ($N = 93,096$)

		Close in time	
		No ($\tau_{ij} = 0$)	Yes ($\tau_{ij} = 1$)
Close in space	No ($\sigma_{ij} = 0$)	26,915	64,023
	Yes ($\sigma_{ij} = 1$)	1,553	$X = 605$

The same calculations were made for the 0.5 threshold rule (table 6.3). According to this criterion there are $n = 530$ observed transitions between 1887 and 1934. Out of 140,808 possible pairs of transitions 808 were close in time and in space.

Table 6.3.: Knox contingency table – 0.5 threshold rule ($N = 140,185$)

		Close in time	
		No ($\tau_{ij} = 0$)	Yes ($\tau_{ij} = 1$)
Close in space	No ($\sigma_{ij} = 0$)	71,323	66,080
	Yes ($\sigma_{ij} = 1$)	1,974	$X = 808$

[5] 213 municipalities out of 645 had their transition before 1887 or after 1934, as defined by the 10% drop rule (see table 6.1).

The next step is to evaluate whether the X values calculated above are statistically significant. The null hypothesis (H_0) that needs to be tested is the absence of space-time interaction, i.e. the time and location of transition are randomly distributed.

In order to operate the Knox test a reference distribution was created using Monte Carlo simulation. The idea is to create new values of X based on the permutation of time or place of occurrence of events. Starting from a list containing time and location of transitions, each iteration of the simulation consists in (i) reshuffling the time of onset while holding the municipalities constant[6]; and (ii) computing a new Knox statistic X.

The distributions based on 1,000 Monte Carlo iterations are presented on figure 6.9. The graphic plots the level of the Knox statistic X against p-values, which express the probability that X from a random permutation is greater than the observed X.

In order to reject H_0 with a 95% significance level we need a Knox statistic of approximately 375 for the 0.5 threshold rule test and of 400 for the 10% drop rule test. The X values calculated for both criteria are much higher: 808 and 605 respectively (as indicated by the vertical lines in figure 6.9). In fact, none of the values obtained by the simulations were as high as the Knox statistic calculated with the I_g time series.

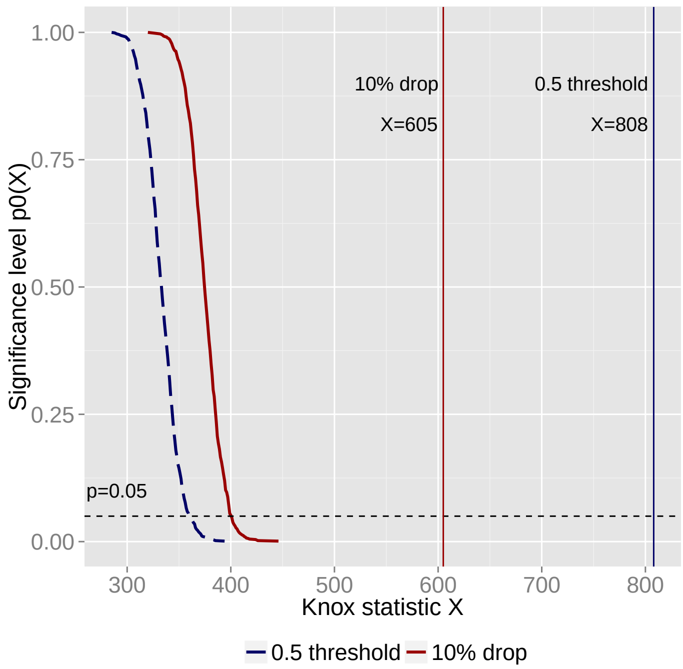


Figure 6.9.: Knox test: reference distributions based on 1,000 Monte Carlo permutations

[6]Alternatively, locations can be reshuffles while time is held constant.

In summary, the Knox test provides an objective evaluation of the spatial-temporal clustering of fertility decline in Belgium. For both transition criteria the space-time interaction was highly significant: municipalities that are close in space tended to experience their fertility transition within the same period of time.

6.4. Discussion

The I_g time series calculated between 1887 and 1934 does not cover the entire process of fertility transition in Belgium. In 1887, fertility decline was well underway in the pioneering zone situated in the south-west of Wallonia; conversely, at the end of the series fertility was only beginning its fall in the latecomer zone in the north-east of Flanders. Even so, the high level of spatial and temporal detail provided by the I_g time series allowed for the production of a thorough description of the spatial-temporal patterns of fertility decline in Belgium, using different and complementary methods for space-time analysis.

Together, the analyses carried out in this chapter reveal interesting features of the transition process. In particular, several results are consistent with the hypothesis that diffusion effects have shaped the spread of modern fertility behaviour in space and time.

The maps sequence of marital fertility levels (figures 6.1 and 6.2) reveals the strikingly contiguous path of the spread of modern fertility behaviour over time. Fertility decline gradually propagates among neighbouring areas, year after year, similarly to a contagious process. This observation was reinforced by the results of the spatial analysis (subsection 6.3.1), which showed the high spatial dependence of I_g throughout the entire period. At each year in the time series, I_g levels were highly clustered in space: municipalities' fertility levels were significantly similar to that of their surroundings.

In section 6.2 the transition year of each municipality was defined using two criteria: the 10% drop rule and the 0.5 threshold rule. The former refers to the moment of 'outbreak' of fertility decline, whereas the latter corresponds to a moment when the fertility transition reaches an advanced stage. These criteria provided an objective way of analysing the timing and speed of fertility decline in Belgium. The maps depicting the spatial distribution of transition years (figure 6.4) suggest that both the timing and the pace of transition followed a specific spatial logic. On the one hand, there are remarkable differences in the timing of the transition across the territory; on the other hand, the maps reveal contiguous zones which experienced fertility transition at about the same time and at the same pace. This space-time interaction in the fertility timing and pace was confirmed by the Knox test (subsection 6.3.2): a statistically significant number of municipalities that are close in space went through the fertility transition in the same period of time.

In summary, there is a clear spatial-temporal clustering in the transition process in Belgium. To the extent that social interactions are more intense between adjoining areas, the space-time logic observed here could be the result of diffusion effects. Ideas and values about fertility decline would have gradually spread by the means of social interaction, from one municipality to the other.

Apart from the space-time interaction, the specific path of fertility transition revealed in this chapter hints at the importance of diffusion.

An interesting outcome of the maps (figures 6.1 6.2 and 6.4) is that municipalities close to the French border experienced an early start of the fertility decline. An early-transition layer of French-speaking *communes* stretches along the French border, from the province of Hainaut until the extreme south of Belgium. It is composed of very different municipalities, ranging from rural (e.g. Chimay, Couvin and the extreme-south of the Ardennes) to highly industrialised (Charleroi and Mons). Similarly, Flemish municipalities at the French border started fertility decline earlier than most of the rural areas in Flanders. It is known that fertility transition in France was way ahead in the nineteenth century. The French *départements* located at the Belgian border (Nord, Aisne, Ardennes and Meuse) had I_g levels below 0.7 already in 1831; what is more, the French *département* of Ardennes – adjoining the pioneering zone in the south of Belgium (Chimay, Couvin) – had particularly low fertility levels, with an I_g value of 0.41 in 1886 (Coale and Watkins, 1986, app. A). The diffusion of innovative values and attitudes coming from France could have triggered the fertility decline in the bordering zones.

In contrast, the linguistic border seems to have delayed the spread of modern fertility behaviour in Belgium. Fertility levels were persistently contrasted in both sides of the border. While the transition propagated freely in Wallonia, Flemish municipalities maintained high fertility levels until the 1910s. Most of the Dutch-speaking municipalities situated at the border started the transition process about two decades later than their French-speaking neighbours (figure 6.4). It is reasonable to think that the linguistic border worked as a communication barrier that hindered social interaction between French- and Dutch-speaking populations, and thus prevented the diffusion of modern behaviour towards the north of the country. However, once the transition finally began in Flanders it spread very quickly across the region (as suggested by the transition curves in figure 6.5a).

Finally, the gradual spread of fertility decline took a contiguous path along the industrial and urban axes in Belgium: first the Walloon industrial axis Charleroi-Namur-Liège; and later the northern axes Brussels-Antwerp and Brussels-Ghent-Bruges. These axes are expected to be areas of relatively intense social interaction. The presence of roads and railways connecting cities, as well as the number of internal migrants and commuters favoured by the economic activity (Mahain, 1910; Laffut, 1998) could have helped the spread of new ideas about fertility behaviour. Conversely, fertility decline was delayed in the zones that were less connected to the industrial and urban axes and located relatively far from the French border. This is namely the case of the eastern Ardennes in Wallonia and the province of Limburg in Flanders.

In conclusion, the spatial-temporal patterns of fertility decline in Belgium described in this chapter are consistent with the hypothesis that diffusion effects were at play during the transition, shaping the spread of modern fertility behaviour across the territory. However, it is also possible that the fertility patterns that we observed are merely the outcome of structural and cultural changes in space and time, rather than diffusion effects. In other words, the fertility patterns observed here can only be considered as evidence of diffusion if they were not shaped by structural and cultural changes in space and time. Therefore, in order to detect diffusion it is essential to control for the space-time patterns of all the other variables that are likely to influence fertility behaviour. This is done by a diffusion causal model in the next chapter.

Chapter 7.

Macro-level contagion model

The analyses carried out in the last chapter revealed the remarkable space-time logic of the fertility transition process in Belgium, with modern fertility gradually unfolding among neighbouring areas, year after year. At first glance, the specific path of the Belgian transition could suggest that diffusion effects were at play. However, other factors – such as socioeconomic and cultural changes – could also have played a role in the spread of modern fertility behaviour. In fact, space-time clustering of demographic changes is only evidence of contagion if it is not shaped by the space-time patterns of other relevant variables (Schmertmann et al., 2010; Goldstein and Klüsener, 2014).

This chapter investigates the underlying mechanisms of the spatial-temporal patterns of fertility decline in Belgium. In particular, it aims at examining to what extent these patterns were shaped by diffusion, net of the effect of cultural and structural changes in space and time.

To this end, a causal diffusion model was conceived based on event-history analysis. Originally designed for the study of micro data, event-history analysis has proved to be a powerful method for the study of social change at the macro level as well (Hedström, 1994; Beauchemin and Schoumaker, 2009). In our case it offers a dynamic framework for the analysis of fertility decline, combining both its temporal and spatial dimensions.

The time series of aggregate indicators compiled for this thesis were treated in this chapter as a longitudinal dataset, in which municipalities are followed up, year by year, between 1888 and 1934. In such a way, a macro event-history model was designed in order to estimate the effects of contagion, as well as of socioeconomic and cultural variables, on the municipalities' likelihood to start fertility transition.

The first section of this chapter presents the model design. Section 7.2 introduces the covariates included in the model, as well as the hypotheses linked to each one. Section 7.3 presents the results, followed by a discussion on their implications in respect to the hypotheses.

7.1. Discrete-time event-history model

The motivation behind causal diffusion models is to isolate contagion effects from all the other variables that are likely to influence the dependent variable. From a macro perspective, the occurrence of a given event in spatial unit i at time t is a function of the occurrence of the same event in geographically close units j at time $t-1$, as well as of all the other relevant variables at time $t-1$ (see chapter 1, subsection 1.2.1; and chapter 5, subsection 5.1.2).

This general framework was adapted here for the study of diffusion of modern fertility behaviour in a discrete-time event-history model. The event of interest is the fertility decline in a given municipality at a given moment (Y_{it}). The model can be represented as follows:

$$\ln\left(\frac{p(Y_{it})}{1-p(Y_{it})}\right) = \alpha_t + \delta Y_{jt-1} + \boldsymbol{\beta}\boldsymbol{X}_{it-.} + \varepsilon_{it} \tag{7.1}$$

The dependent variable is the logit-transformation of the probability of municipality i to experience fertility decline at time t. The right-hand side of the equation is composed of two main components (other than the constant α_t and the error term ε_{it}). $\boldsymbol{X}_{it-.}$ is a set of structural and cultural characteristics of municipality i at previous years[1], which are likely to influence its chances to undergo fertility decline at time t. Y_{jt-1} is a contagion component. For a given municipality i it accounts for the first occurrence of fertility decline among its neighbouring municipalities j at time $t-1$. The coefficient δ can be thus considered as the diffusion effect on fertility decline, net of other relevant factors that might influence the transition timing.

A crucial matter in the application of this model is obviously the definition of the dependent variable, which must account for the occurrence of the event 'fertility decline' – Y_{it} – in a binary form. Two models were conceived, one for each definition of transition discussed in the last chapter (see chapter 6, subsection 6.2.1):

- In the *10% drop model* municipality i is said to experience fertility transition at the year in which its fertility level, measured by the marital fertility index I_g, permanently drops by 10% compared to the 1887 level.
- As for the *0.5 threshold model* the moment of fertility decline is defined as the year in which I_g falls below 0.5 and does not rise above this threshold in subsequent years.

Whereas the first model concerns the onset of fertility decline, the second model refers to the moment in which municipalities reached an advanced stage of the fertility transition.

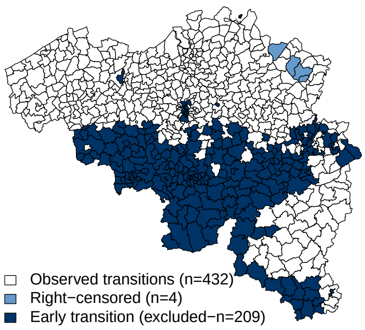
In practice, each model is based on a municipality-year dataset, in which municipalities appear as many times as the number of years 'at risk' of experiencing fertility decline. The time origin is 1888. The last row in which a municipality appears in the dataset

[1] Because I use different time lags for different variables, time is represented as '$t-.$' for the variables vector $\boldsymbol{X}$.

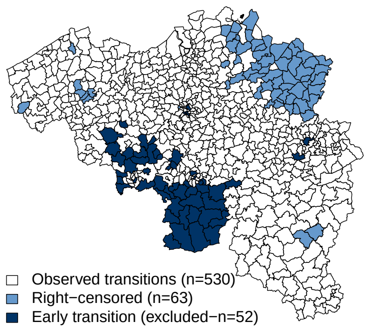
corresponds either to its transition year or to censoring. Right-censoring takes place in 1934, i.e. the end of the I_g time series. Municipalities which experienced fertility decline before 1888 are considered as non-eligible and are excluded from the analysis (chapter 6, subsection 6.2.1).

For example, the municipality of Charleroi experienced its transition before 1888 by both definitions of fertility decline: it is thus non-eligible in both models. The municipality of Ronse (illustrated in figure 6.3) experienced the onset of fertility transition in 1901, as defined by the 10% drop rule. Therefore, it appears fourteen times in the 10% drop model dataset: the variable takes the value 0 for each year between 1888 and 1900 and value 1 in 1901. As for the 0.5 threshold model the municipality of Ronse has nineteen rows in the corresponding dataset until 1906 when its I_g level falls below 0.5. Lommel, in the province of Limburg had a very late fertility decline and is right-censored in both municipality-year datasets after 46 observation years.

The maps in figure 7.1 present the 645 municipalities according to their status in the two models: observed transition, right-censored and non-eligible (early transition). Nearly one third of the municipalities are non-eligible in the 10% drop model and only 436 municipalities were included (from which four were right-censored), totalising 6,780 municipality-years. The territory covered by this model is mainly composed by the Dutch-speaking part of Belgium and the Ardennes. The 0.5 threshold model comprises more municipalities across the whole country (593), as only 52 were non-eligible. On the other hand, right-censoring was relatively more frequent in this model (63 cases). In total, the municipality-year dataset for the 0.5 threshold model counts 17,082 rows.



(a) 10% drop model



(b) 0.5 threshold model

Figure 7.1.: Municipalities included or censored in each model

7.2. Covariates

7.2.1. Contagion variable

The contagion variable – Y_{jt-1} – is a key covariate in the models. For a given municipality i at time t it accounts for the presence or absence of at least one contiguous municipality j which experienced fertility decline prior to t. This *neighbouring transition* variable takes value 0 as long as no neighbouring municipality has started fertility decline and value 1 once the decline starts in the first neighbour.

Table 7.1 presents an example of how the neighbouring transition variable operates in the municipality-year datasets. Let us consider a municipality i whose fertility decline started in 1897. Until 1896 the binary transition variable Y_{it} has value 0; in the last row of appearance, it takes value 1. In 1893 municipality j was the first neighbour to start the decline. From this moment on the neighbouring transition variable Y_{jt-1} takes value 1, until the transition of i.

Table 7.1.: Example of the transition variable Y_{it} and the corresponding neighbouring transition variable Y_{jt-1} in the municipality-year datasets for a given municipality

Year	Y_{it}	Y_{jt-1}
1888	0	0
1889	0	0
1890	0	0
1891	0	0
1892	0	0
1893	0	1
1894	0	1
1895	0	1
1896	0	1
1897	1	1

Although the municipalities with fertility decline prior to 1888 are excluded from the dependent variable (non-eligible), they participate in the contagion variable. For instance, if a given municipality from the dataset has a non-eligible neighbour its neighbouring transition variable has value 1 from the time origin on.

Needless to say, the construction of the neighbouring transition variable depends on the definition of transition year and was adapted for the criteria used in each model – 10% drop and 0.5 threshold respectively.

In summary, the neighbouring transition variable will allow for tests on whether the presence of at least one contiguous municipality that has started fertility decline at $t-1$ affects the likelihood, for a given municipality i, of starting its decline at t. The variable can thus be seen as a spatial-temporal lagged term. Its impact, which represents the diffusion effect, is expected to be positive and highly significant.

7.2.2. Cultural and socioeconomic variables

The vector $\boldsymbol{X}_{it-.}$ in equation 7.1 must comprise all the variables that are likely to influence fertility behaviour and that might have shaped the spread of modern fertility in space and time. Therefore, it includes eight indicators compiled from censuses and the *Mouvement de la population et de l'état civil* at different moments between 1880 and 1930[2]. The time series of indicators allow for the capture of changes in the cultural and socioeconomic conditions in space and time during the observation period, as well as in the structure of municipalities' social networks. The computation of each indicator is recalled in table 7.4. Descriptive statistics for 1890 and 1920 are presented in table 7.2.

Table 7.2.: Descriptive statistics of covariates in 1890 and 1920 calculated on the 645 municipalities

Covariate	Year	Mean	St. Dev.	Min	Max
Proportion male blue-collar (%)	1890	26.9	15.6	4.6	64.8
	1920	36.1	13.1	8.4	65.9
Proportion female labour (%)	1890	15.8	7.2	5.4	44.5
	1920	15.6	7.2	5.0	36.5
Literacy rate (%)	1890	62.7	10.1	26.5	87.12
	1920	82.9	4.6	62.3	92.5
Infant mortality rate (‰)	1890	144.3	37.7	97.7	304.2
	1920	105.1	26.9	42.8	249.4
Proportion French-speaking (%)	1890	50.2	44.0	1.3	100.0
	1920	49.2	42.3	0.5	98.8
Marriages in Lent index (%)	1888	49.0	27.5	0.0	158.5
	1921	62.9	28.8	0.0	141.2
Proportion non-natives (%)	1890	31.2	11.8	2.8	78.5
	1920	36.9	13.0	7.1	95.6
Population density (inhab./km^2)	1890	539	1,710	20	26,203
	1920	721	2,254	25	28,085

Sources: *Mouvement de la population et de l'état civil* and Population Censuses

Four **socioeconomic variables** reflect different aspects of the structural changes that might have altered couples' preferences in respect to family size:

- The *proportion of male adult population employed as blue-collar in the industrial sector* is an indicator of the municipalities' industrialisation level. Industrialisation is thought to have changed the costs and benefits of childbearing: large families become economically disadvantageous in an industrial context (Bongaarts and

[2]See chapter 3 for a detailed discussion on the choice and construction of indicators from the raw data.

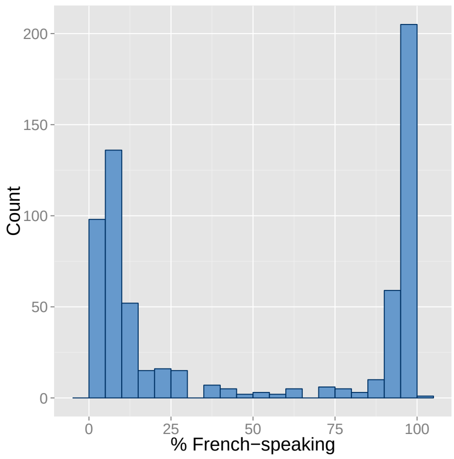
Watkins, 1996; Kirk, 1996) and are increasingly perceived as an obstacle to social mobility (Eggerickx, 2004). Therefore, the industrialisation index is likely to have a positive impact on the municipalities' odds of experiencing fertility decline.

- Likewise, the *female labour force employed in industrial and trade sectors*, i.e. non-traditional agricultural sectors, might also have increased the costs of childbearing and contributed to fertility decline (Folbre, 1983; Galloway et al., 1994). Besides, working women would have more opportunities to be familiarised with the world outside the household and thus more exposed to information about the costs and benefits of childrearing and the moral acceptability of birth limitation (McDonald, 2000; Mason, 2001). The progression in female labour should also have a positive effect on the timing of fertility decline.
- The municipalities' *literacy rate* is employed as a proxy for the education level. Education would have given individuals access to information and provided them with autonomy to make conscious reproductive choices (McDonald, 2000; Mason, 2001). Furthermore, children's education have a direct impact on the costs of childrearing, which would contribute to birth limitation. As a result, as literacy rates rises in a municipality, its likelihood of adopting modern fertility should also rise.
- Finally, improvements in the chances of child survival – measured here by the *infant mortality rate* – would imply that couples have to bear less children in order to attain their desired family size (Easterlin and Crimmins, 1985; van de Walle, 1986; Reher, 1999). This variable is thus expected to have a negative relation with the timing of fertility decline: a fall in the infant mortality rate should be associated with higher odds of starting fertility transition.

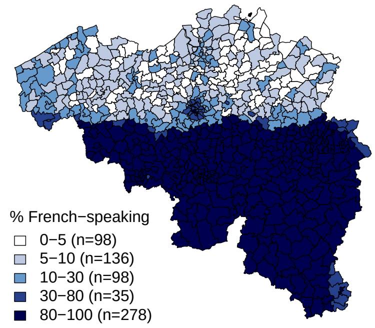
Two **cultural variables** refer to the municipalities' secularisation level and linguistic distribution:

- Secularisation is known to be an important component of the fertility transition: the shift away from a traditional and religious frame of reference towards new values would have made birth control morally acceptable and changed couples' attitudes in respect to fertility (Lesthaeghe, 1977; Lesthaeghe and Neels, 2002). The proxy for secularisation is obtained by the *Marriages in Lent index* (MLI). As marriages during the Lent were proscribed by the Catholic Church, the intensity of marriages in March can be used as an indicator of the respect of religious norms and the moral and social control imposed by the community (Lesthaeghe, 1991). The indicator relates the number of marriages in March to the monthly average over an year, expressed in percent. An index close to 100% indicates that marriages in March are as common as in any other month[3] and marriage ban during Lent is generally not observed in the municipality. Higher values of the

[3]Note that the indicator might have values higher than 100% if marriages in March are more frequent than in other months.



(a) Histogram



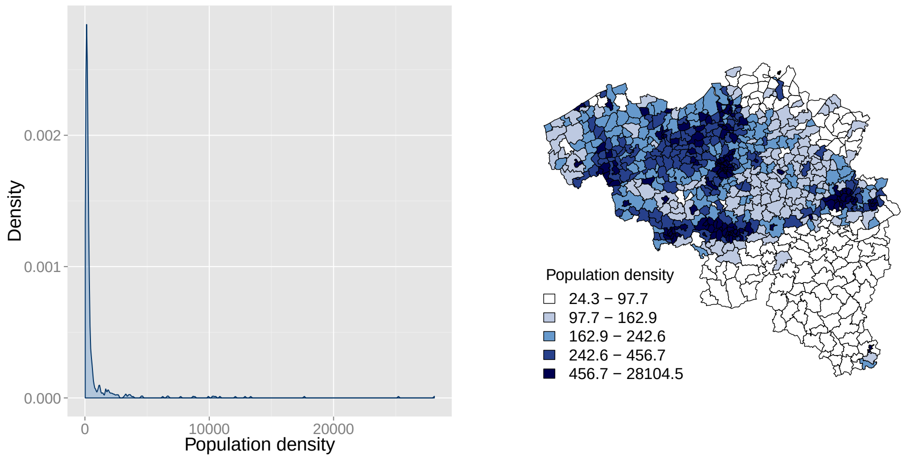
(b) Spatial distribution

Sources: *Mouvement de la population et de l'état civil* and Population Censuses

Figure 7.2.: Municipalities by proportion of French-speaking population in 1910 (%)

indicator are associated with higher levels of secularisation. The secularisation index is thus expected to have a positive impact on the odds of starting fertility transition.

- It is known that secular ideas and values were disseminated earlier within French-speaking populations (Lesthaeghe and Lopez-Gay, 2013) and that the presence of Francophone minorities in Flanders contributed to the spread of modern fertility behaviour (Van Bavel, 2004a). In this sense, the *proportion of French-speaking population* is an indicator of the municipalities' exposure to the progressive ideas and attitudes that circulated in the 'Francophone world'. Because of the linguistic composition of Belgium the distribution of this variable across the municipalities is highly asymmetric (figure 7.2a). Most of the Walloon *communes* have more than 80% of French-speaking inhabitants, whereas this proportion is limited to 15% in most of Flanders. In order to separate the effect of this variable in both sides of the linguistic border the municipalities were grouped into five categories, as shown in figure 7.2b. Municipalities with Francophone majority (80–100%) are assembled in one group, which covers most of Wallonia. The second group (30–80%) is composed of only 35 bilingual municipalities situated at the linguistic border, at the Luxembourg and Dutch borders and in Brussels. The other three groups (less than 30%) convey the presence of French-speaking minorities in Flanders. Higher proportions of Francophones are expected to be associated with higher odds of starting fertility decline.



(a) Kernel density plot (b) Spatial distribution

Sources: *Mouvement de la population et de l'état civil* and Population Censuses

Figure 7.3.: Municipalities by population density in 1910 (inhab./km^2)

Finally, the variables set $\boldsymbol{X}_{it-.}$ includes two indicators conveying features of municipalities' **social networks**:

- The *Proportion of non-natives* is a measure of the heterogeneity of a municipality's population. New values and attitudes can flow more freely within heterogeneous networks – or 'weak ties' (Granovetter, 1973). Residents born in another *commune* and socialised in a different context might bring with them innovative views in respect to fertility behaviour. In addition to that, they are likely to be less embedded in the local social networks and thus less subjected to moral control regarding traditional fertility behaviour. Therefore, higher proportions of non-natives should accelerate the course of fertility transition and have a positive effect on the dependent variable.
- The *population density* is an indicator of the intensity of social interactions. In municipalities where population density is high social interaction should be more intense and new ideas about fertility should flow more easily, which could have a positive impact on fertility decline. As figure 7.3a shows, the distribution of this variable is highly asymmetric. Whereas most of the spatial units have less than 2,000 inhabitants per square kilometre, a number of highly urbanised municipalities have much higher figures. The map in figure 7.3b shows the municipalities' distribution according to five quantiles of population density. The highest quantile assembles figures ranging from 450 to 28,000 inhabitants per square kilometre.

As suggested by the descriptive statistics in table 7.2, the variables globally reflect the structural and cultural changes in Belgium since the end of the nineteenth century[4]. Overall, the period was marked by a rise in industrial work and literacy levels and a fall in mortality rates. Also, secularisation progressed, as suggested by the rise in the Marriages in Lent index. On the other hand, the female labour force remained stable over the period. This is probably due to the fact that female participation in traditional proto-industrial sectors was already high at the turn of the twentieth century, especially in Flanders (Lesthaeghe, 1977).

The spatial distribution of covariates in mid-period (1910) is depicted by the maps in figures 7.2b, 7.3b and 7.4. The major urban axes – Charleroi-Namur-Liège and Brussels-Antwerp – display the highest levels of industrialisation, secularisation, population density and spatial mobility, with high proportions of non-natives. As shown in chapter 6, it was along these axes that fertility decline gradually spread over the years. On the other hand, the latecomer zones in the transition – the Ardennes and the province of Limburg – are characterised by the lowest levels of industrialisation and population density. In general, literacy rates were higher in French-speaking municipalities, especially in the south of the country. Finally, the spatial distributions of infant mortality and female labour seem to be closely linked. In particular, these two parameters are high in the north-west of the country, which could be due to the specific occupational structure in this area and poor living conditions[5].

This brief description shows that the associations between the different variables and the fertility transition are complex, even if we only consider a cross-sectional perspective. The event-history framework will allow to investigate in a dynamic perspective how the interplay of these different variables might have shaped the spatial-temporal patterns of fertility decline.

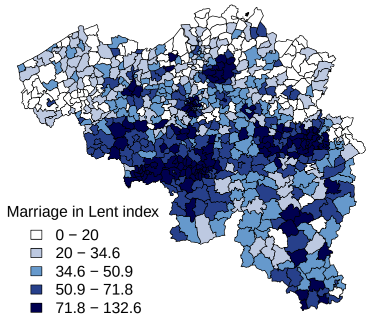
The eight indicators described above were computed for each municipality, roughly at ten-year intervals between 1880 and 1930 (see chapter 3). Yearly time series of covariates were obtained through linear interpolation[6]. This way, the value of each indicator may vary year after year in the event-history models.

Variables were included in the model using different time lags. In the absence of diffusion socioeconomic and cultural shifts are expected to have an immediate impact on fertility behaviour. Therefore, most of the variables were lagged by one year only. However, some of the covariates are related to diffusion processes within the

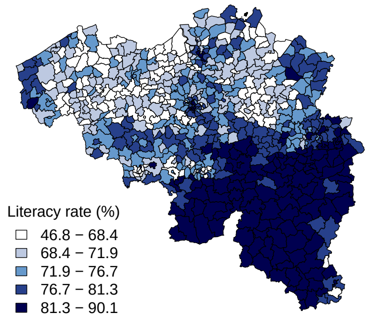
[4] For a thorough analysis of the socioeconomic and social evolutions in Belgium using similar indicators at the *arrondissement* level, see Lesthaeghe (1977, ch. 2).

[5] In some parts of Belgium – particularly in Flanders – women would often resume their jobs right after childbearing. Breastfeeding was therefore limited in those instances. The contamination of feeding bottles in poor areas was a major factor in the high infant mortality. On this subject see Masuy-Stroobant (1983).

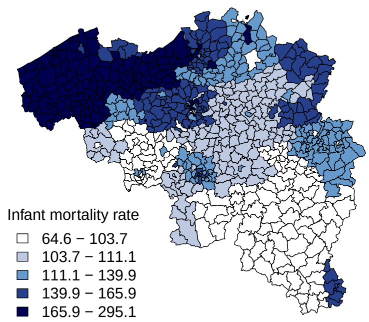
[6] The same strategy was used by Hedström (1994) in an event-history model using covariates computed for census years in Sweden.



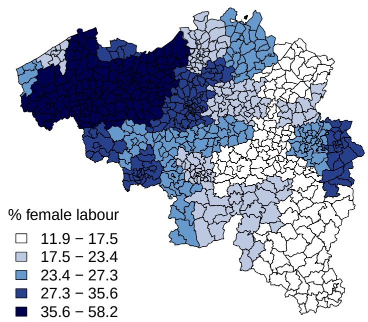
(a) Marriages in Lent index (%)



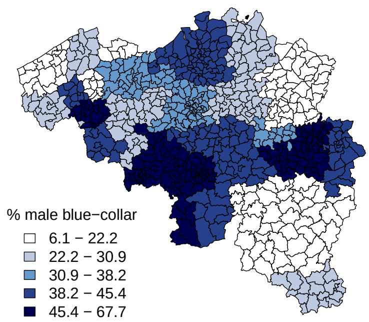
(b) Literacy rate (%)



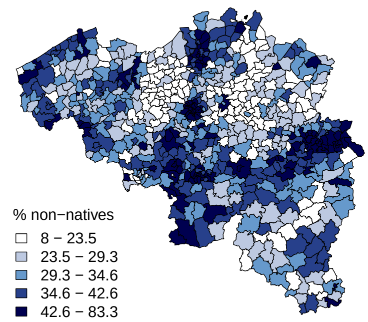
(c) Infant mortality rate (‰)



(d) Female labour (%)



(e) Proportion male blue-collar (%)



(f) Proportion non natives (%)

Sources: *Mouvement de la population et de l'état civil* and Population Censuses

Figure 7.4.: Spatial distribution of covariates in 1910

municipalities. For example, a rise in the proportion French-speaking in a municipality would have a delayed impact on fertility behaviour because diffusion mechanisms within the municipality would have to take place through social interaction. The same is true for the proportion non-natives and population density. For this reason these three variables were included in the models with a five-year lag[7].

There are reasons to believe that some numerical covariates included in the models have a nonlinear relationship with the dependent variable. In other words, the effects of numerical variables on the odds of experiencing fertility decline might vary with their level. For example, a rise in the proportion of male blue-collars is expected to have a positive impact on the odds of starting fertility decline; however, the change between 10 and 20% (corresponding to the onset of industrialisation in a municipality) may have a greater impact than a change between 70 and 80% (in a municipality that is already highly industrialised).

Each numerical variable was tested for its potential nonlinear effect[8]. Two covariates were shown to have a nonlinear relationship with the dependent variable: population density and industrialisation (proportion male blue-collar). Therefore, a quadratic term of these covariates was included in the final models.

7.2.3. Time

The principle of event-history analysis – as of survival analysis in general – is to model the event of interest as a function of its time of occurrence. Time is thus a basic control variable that must be included in the models.

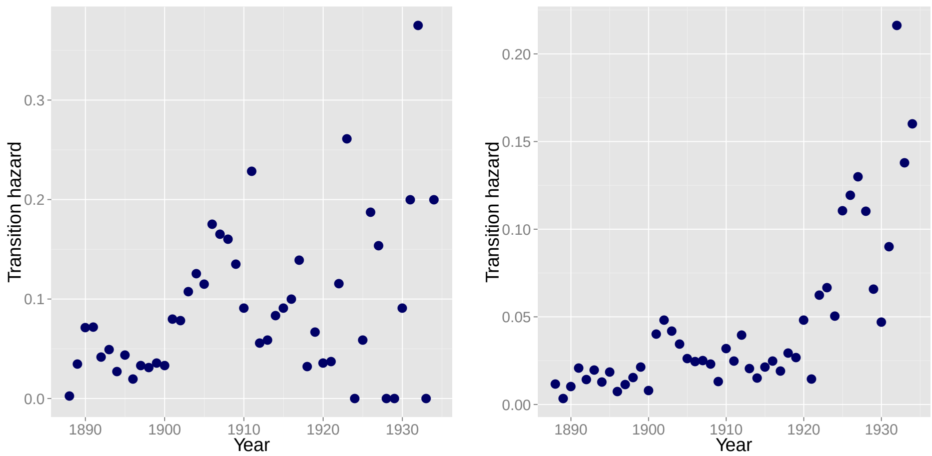
Figure 7.5 shows the transition hazards by year in the two municipality-years datasets. For the 0.5 threshold model (figure 7.5b) a trend can be distinguished with transition hazards increasing exponentially over the years, although there are important fluctuations after 1920. In the case of the 10% drop model (figure 7.5a), in contrast, transition hazards seem to take random values after 1910. These fluctuations are probably due to the small number of transitions (and of municipalities ‘at risk’ of transition) in the later stages of the fertility decline.

In order to avoid random fluctuations and to take into account the non-linear trend over the years, time was included in the models as a categorial variable (with roughly five-year intervals). Table 7.3 shows the distribution of municipality-years of both datasets into the ten categories of the year variable, as well as the yearly transition hazards. In general, transition hazards increase over the years in both models. This is an expected outcome of the transition process and are consistent with the analysis of the transition pace in chapter 6: after a certain number of municipalities experience

[7]Tests with the event-history models have shown, nonetheless, that a variation from one- to five-year lags has very little effect on the results.

[8]In practice, models mere estimated including the squared form of each variable at a time. The effect and significance level of these quadratic terms indicated the presence or absence of nonlinear effects.

fertility decline, the adoption of modern fertility behaviour rapidly spread, accelerating the course of the transition.



(a) 10% drop model

(b) 0.5 threshold model

Sources: *Mouvement de la population et de l'état civil* and Population Censuses

Figure 7.5.: Municipalities' transition hazards by year

Table 7.3.: Distribution of municipality-years by year (ten categories) in the two models datasets

Year	10% drop model			0.5 threshold model		
	N. munic.-years	N. transitions	Transition hazards (year)	N. munic.-years	N. transitions	Transition hazard (year)
1888–1890	1,291	46	0.012	1,763	15	0.003
1891–1895	1,750	83	0.009	2,789	48	0.003
1896–1900	1,453	44	0.006	2,589	33	0.003
1901–1905	1,101	109	0.020	2,283	88	0.008
1906–1910	553	84	0.030	1,952	46	0.005
1911–1915	267	30	0.022	1,718	42	0.005
1916–1920	165	13	0.016	1,529	45	0.006
1921–1925	110	11	0.020	1,267	75	0.012
1926–1930	62	6	0.019	797	79	0.020
1931–1934	28	6	0.054	395	59	0.037

Sources: *Mouvement de la population et de l'état civil* and Population Censuses

Table 7.4 brings an overview of the covariates included in the models. All the covariates are time-varying.

Table 7.4.: The independent variables included in the event-history models

	Variable	Computation	Measure	Type	Time lag (years)	Expected effect
Diffusion	Neighbouring transition	Presence or absence of at least one neighbouring municipality which has previously started fertility decline	Contagion effect	Binary	1	+
Socioeconomic	Industrialisation	Proportion of men working as blue-collar among the districts' male population aged 15 to 65	Proxy of the districts' industrialisation level	Numerical	1	+
	Female labour	Proportion of women working in industry and trade among districts' female population aged 15 tà 65	Participation of women in non-traditional sectors	Numerical	1	+
	Literacy rate	Share of literate inhabitants among the municipalities' total population	Education	Numerical	1	+
	Infant mortality rate	Number of deaths before age one among the districts' total number of living births	Chances of child survival	Numerical	1	−
Cultural	Secularisation	Number of marriages in March divided by the mean monthly number of marriages over the year	Respect of the norms imposed by the church and by social and moral control	Numerical	1	+
	% French-speaking	Share of people with knowledge of French (as first or second language) among the municipalities' total population	Exposure to the Francophone progressive values	Categorial	5	+
Networks	% non-natives	Proportion of residents born in another *commune* in the total population	Networks heterogeneity	Numerical	5	+
	Population density	Number of inhabitants per km^2	Intensity of social interactions	Numerical	5	+
Control	Year	-	-	Categorial	-	+

7.3. Event-history analysis

7.3.1. Models computation

The discrete-time event-history models designed in this chapter are aimed at determining the impact of several independent variables on the the municipalities' likelihood of experiencing fertility decline. Two models were conceived, one for each definition of transition timing. The 10% drop model tests the municipalities' likelihood to start fertility decline, i.e. to experience a 10% fall of its pre-transitional marital fertility level. The 0.5 threshold model concerns the municipalities' odds of reaching an advanced stage of the fertility transition, with an I_g value below 0.5. It is important to bear in mind that, whereas the first model concern mostly municipalities in Flanders and in the Ardennes, the second one covers a broader territory, including therefore a more diverse cultural and socioeconomic landscape.

For each model I first tested the raw effect of the neighbouring transition variable Y_{jt-1}. Next, full models were computed including all the covariates.

The models were estimated by binary logistic regression. Some of the numerical covariates have many outliers, which could lead to biased estimations of standard errors. Therefore, in order to produce more robust results standard errors were computed using bootstrap with 1,000 replications.

I used different scales for numerical covariates in order to simplify the interpretation of odds ratios in the results. Proportion variables are expressed by ten percentage points: the odds ratios represent thus the effect of a 10% increase in the variables. Population density is expressed in 1,000 inhabitants per square kilometre.

7.3.2. Results

Table 7.5 displays the results of the event-history models. The table presents the regressions' odds ratios, as well as goodness-of-fit parameters.

The evolution of municipalities' transition odds over the years in both models are consistent with the findings in chapter 6. In particular, the results closely reflect the transition profiles portrayed by the curves in figure 6.5. For the 10% drop model, compared to the reference years of 1888–1890, municipalities had smaller odds of starting fertility decline in 1896–1900. In fact, the turn of the twentieth century corresponds to the moment in which the linguistic border seems to have halted the spread of modern fertility into Flanders (see maps sequence in figure 6.1). Once the decline started in Flanders between 1900 and 1910, the transition process accelerated, as indicated by the high and significant transition odds ratios in this period. After that the transition resumed its courses at slower but steady rates. In the 0.5 model transition odds are markedly higher from the early twentieth century on, led by the earlier decline in Wallonia. The process accelerated in the 1920's, when an increasing number of Flemish municipalities finally caught up in the transition process.

Table 7.5.: Event-history analysis of municipalities' likelihood of experiencing fertility decline: logit regression results

Odds ratios	10% drop model		0.5 threshold model	
	raw	net	raw	net
Time variable				
Year (ref = 1888–1890)				
1891–1895	1.015	1.244	1.815	1.915
1896–1900	0.570*	0.708	1.144	1.148
1901–1905	1.795**	2.383***	3.174***	4.490***
1906–1910	2.618***	4.253***	1.954*	4.800***
1911–1915	1.634*	3.628***	1.562	4.720***
1916–1920	1.114	2.796*	1.610	4.463***
1921–1925	1.354	3.390**	2.598**	6.379***
1926–1930	1.284	3.108	4.085***	9.523***
1930–1934	3.268	8.637**	6.604***	15.495***
Contagion variable				
Neighbouring transition (ref = 0)	5.781***	3.908***	16.503***	6.781***
Socioeconomic variables				
Literacy rate (scale: 10%)		0.980		1.366**
Infant mortality rate (scale: 10‰)		1.038*		0.970
Female labour (scale: 10% female workers)		1.164*		0.925
Industrialisation (scale: 10% male blue-collar)		2.001*		5.466***
Industrialisation-squared		0.911*		0.846***
Cultural variables				
% French-speaking (ref = 0–5%)				
5–10%		1.207		1.275
10–30%		1.679**		1.530*
30–80%		1.842*		1.732*
80–100%		3.454***		4.459***
Secularisation (scale: 10% Marriages in Lent index)		1.027		1.044*
Social networks variables				
% non-natives (scale: 10%)		0.986		1.019
Population density (scale: 1,000 inh./km^2)		1.919**		2.429***
Population density-squared		0.955		0.946**
Models parameters				
N. municipality-years	6,780	6,780	17,082	17,082
df	11	24	11	24
Deviance ($-2LL$)	2,909	2,791	3,812	3,523
AIC	2,931	2,839	3,835	3,571
BIC	3,006	3,003	3,920	3,757

$***\ p < 0.001$; $**\ p < 0.01$; $*\ p < 0.05$
Two-tailed tests performed by bootstrap with 1,000 replications
Sources: *Mouvement de la population et de l'état civil* and Population Censuses

In both models the raw effect of the neighbouring transition variable is positive and highly significant. Municipalities are nearly six times as likely to start fertility transition if a neighbouring municipality has started its transition before (10% drop), and more than sixteen times as likely to reach an advanced stage of fertility decline if a neighbour has already reached that level (0.5 threshold). The much higher effect of this variable in the second model can be explained by the fact that fertility levels are highly clustered in space (as shown by the spatial analysis in chapter 6, subsection 6.3.1). Whereas the 10% drop approach does not entirely depends on the level of marital fertility, the 0.5 threshold approach does refer to a specific value of I_g.

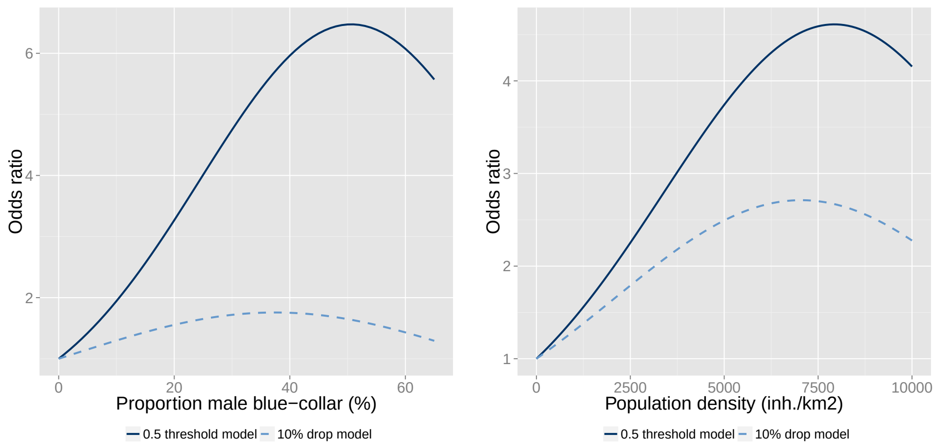
The raw effect of the neighbouring transition variable only reflects the space-time logic of fertility transition. It simply tells us that fertility decline spread gradually over time among adjoining areas, in accordance with the conclusions of the descriptive analysis in chapter 6. However, this gradual spread can be either due to diffusion or to the space-time clustering of other factors that affect fertility behaviour.

The odds ratios of the neighbouring transition variable diminish after the introduction of socioeconomic, cultural and social networks variables, especially in the 0.5 threshold model. But their effect remains considerably high and significant. This indicates that socioeconomic and cultural changes in space and time do account for part of the spatial-temporal patterns of fertility decline, along with diffusion.

The linguistic composition of municipalities seems to have played an important role on the transition timing. Compared to municipalities with a small Francophone minority (less than 5%), those with more than 10% French-speaking are more likely to undergo fertility decline. The odds are much higher for Walloon *communes* with Francophone majority – 3.45 and 4.46 in the two models, respectively, with $p < 0.001$. But even in the north of the linguistic border the presence of French-speaking minorities increases the odds of fertility decline: municipalities with 10 to 30% population that have some knowledge of French are around 80% more likely to adopt modern fertility behaviour, compared to those with less than 5%. In sum, even controlling for socioeconomic factors, the net effect of linguistic composition is shown to be relevant. This results corroborate the hypothesis that, other things being equal, the exposure to the Francophone progressive ideas accelerated the course of the transition.

The effects of female labour and infant mortality are statistically significant only in the first model ($p < 0.05$). Female labour has the expected positive impact: a 10% change in the indicator results in a 30% increase in the municipalities' odds of starting the fertility transition. On the other hand, contrary to our hypothesis, the model results suggest that infant mortality has a positive effect on fertility decline: a 10‰ increase in the infant mortality rate is associated with 4% higher odds of transition onset. A possible explanation for these results of the 10% drop model could be that in the specific circumstances of the East- and West-Flemish occupational structure, low real wages could have triggered the onset of fertility decline and maintained, at the same time, high levels of infant mortality (Galloway et al., 1998), especially in a context of high participation of women in the labour market (Masuy-Stroobant, 1983).

As expected, industrialisation has a positive effect on transition odds. The impact of this variable is particularly high in the 0.5 threshold model, which covers a broader and more heterogeneous space: a 10% increase in the share of male blue-collars in the industrial sector results in in 5.5 higher municipalities' odds of reaching the 0.5 I_g mark ($p < 0.001$). Nevertheless, the effect of industrialisation is not linear (the polynomial terms are significant in both models). Figure 7.6a illustrates the total impact of the industrialisation index. Industrial work has an increasingly positive impact on the odds of fertility transition, but it reaches a maximum effect around 50%. Once a municipality is already highly industrialised the effect of the variable becomes less important. In other words, the onset of industrialisation seems to have a greater impact on the course of the transition, compared to later stages of industrial development.



(a) Industrialisation (b) Population density

Sources: *Mouvement de la population et de l'état civil* and Population Censuses

Figure 7.6.: Net effects of nonlinear variables

Literacy and secularisation have a significant effect only in the 0.5 threshold model. For a 10% increase in the literacy rate the transition odds change by 30% ($p < 0.01$). Similarly, the Marriages in Lent index has a positive and significant effect ($OR = 1.04$ with $p < 0.05$). These results are consistent with the hypotheses. Note that the non-significance of these variables in the first model is certainly due to the fact that the area it covers – Flanders and the Ardennes – is rather homogeneous in terms of socioeconomic and cultural factors (see figure 7.1a). The variation in education and secularisation levels across the first model's territory is probably not large enough to capture the effects of such factors on the transition timing.

Population density has a positive and significant effect on the timing of fertility decline in both models. An increase of 1,000 inhabitants per square kilometre doubles a municipalities' likelihood of experiencing the transition. The polynomial term included in the regressions is significant for the 0.5 threshold model, indicating the nonlinear effect of this variable. Figure 7.6b shows the total effect of population density on the dependent variable, combining both terms (regular and quadratic). The odds ratios increase until around 8,000 inhabitants per square kilometre and slightly decreases after that level. This suggests the existence of a saturation point, after which the impact of an increase in a municipality's density stalls. Either way, these results are consistent with the hypothesis that the intensity of social interaction can accelerate the adoption of modern fertility behaviour. The fact that there is a saturation point can be considered as logical, as the intensity of social interactions in highly dense areas might reach a limit.

It appears from both models that the proportion of non-natives in a municipality's population has no effect on its transition timing. In the 0.5 threshold model, if the population density is dropped (not shown) then the proportion of non-natives has a positive effect ($OR = 1.13$ with $p < 0.05$); this effect is explained away once the population density is accounted for. These results indicate that at the macro level it is the intensity of social interactions, rather than their heterogeneity, that contributes to the transition process.

Table 7.6 shows the residuals deviance tests performed for each covariate. The tests compare the full models to a regression dropping one variable at a time. This allows for the contribution of each covariate to the full models to be assessed. The neighbouring transition variable has by far the greatest contribution in both the 10% drop and the 0.5 threshold models. Besides the contagion term, the most powerful determinants of transition timing in the models are industrialisation, population density and linguistic composition.

To sum up, the event-history analysis confirms the hypothesis that contagion effects played a decisive role in the timing of the fertility transition in Belgium. Even after controlling for socioeconomic and cultural changes over time, there is a substantial space-time logic that remains unexplained – which is captured by the neighbouring transition variable in the models. All things being equal, a given municipality is four to seven times more likely to experience fertility decline if at least one neighbouring municipality has started its transition before. Apart from the relevant contagion effect other factors contributed to the spatial-temporal patterns of the transition. Both models indicate that population density and the presence of French-speaking populations accelerated the course of the transition, which indicates that social interaction might have influenced the adoption of innovative fertility behaviour. The 0.5 threshold model allowed a better exploration of cultural and socioeconomic variables, as it covers a larger and more diverse territory. Both structural and cultural factors were shown to have accelerated the course of the transition, namely secularisation, literacy, and industrialisation.

Table 7.6.: The contribution of each covariate to the full models: residuals deviance tests

	Δdf	$\Delta - 2LL$	
		10% drop model	0.5 threshold model
Neighbouring transition	1	71.03^{**}	207.20^{***}
Literacy rate	1	0.05	11.19^{***}
Infant mortality rate	1	4.19^{*}	1.52
Female labour	1	5.50^{*}	1.35
Industrialisation (regular + squared)	2	11.66^{**}	115.69^{***}
% French-speaking	4	32.95^{***}	51.33^{***}
Secularisation	1	1.29	4.20^{*}
Population density (regular + squared)	2	17.46^{***}	62.05^{***}
% non-natives	1	0.05	0.14

$***\ p < 0.001$; $**\ p < 0.01$; $*\ p < 0.05$, Chi-squared tests
Sources: *Mouvement de la population et de l'état civil* and Population Censuses

It is important to acknowledge that the neighbouring transition variable in the models could be capturing the effect of unobserved variables that are highly clustered in space and time. As discussed in chapter 3, the indicators computed from the available data are rather generic measures of the socioeconomic and cultural aspects of the population. Other variables, such as wage or the percentage catholics, would perhaps yield more accurate results. However, such variables would in practice be more detailed versions of the variables already included in the analyses. It is unlikely that they would be so much more clustered in space and time as to explain away all the observed effect of the neighbouring transition variable.

Following Goldstein and Klüsener (2014), I examined the potential impact of unobserved covariates on the neighbouring transition variable by omitting observed variables from the models (not shown). For the 10% model, if the proportion French-speaking is dropped then the neighbouring transition variable's coefficient increases by 14%. When any other variables are dropped the coefficient decreases. In the 0.5 threshold model, dropping the industrialisation variable leads to the most significant increase in the contagion coefficient, by 18%. All the other variables have little impact. These tests indicate that for unobserved variables to explain away all the positive effect of the neighbouring transition variable, they would require a greater impact than all the variables already included in the model.

In summary, both models, using different ways of accounting for the timing of fertility decline and covering different portions of the territory, indicate a very high impact of the contagion effect. Even though we cannot exclude the possibility that unobserved variables might be responsible for the observed contagion effect, it is very unlikely that the large coefficients obtained in the models would be totally explained away by omitted factors.

7.4. Discussion

The event-history models designed in this chapter provided a dynamic framework to the analysis of the Belgian fertility transition, embracing both the spatial and temporal dimensions of the aggregate dataset. The models aimed at investigating the underlying mechanisms of the spatial-temporal patterns of fertility decline between 1888 and 1934. The transition year of each municipality was estimated by the two approaches discussed in chapter 6: a 10% drop in the initial level of the marital fertility index (I_g) and the year at which I_g fell below the 0.5 threshold. These two approaches were used to build two models. Whereas the 10% drop model concerns the onset of fertility decline, the 0.5 threshold model refers to the moment in which municipalities reached an advanced stage of the fertility transition. Covariates included two main components. The first one – the contagion variable – controlled for the presence of at least one neighbouring municipality which had started its transition beforehand, serving thus as a space-time lagged variable. The second component was a set of indicators time series accounting for the evolution of different aspects of the cultural and socioeconomic macro conditions in space and time, as well as characteristics of municipalities' social networks. Not only did the models produce direct estimates of contagion effects, net of the action of other relevant variables, but they also allowed to examine the other determinants of the timing of fertility decline.

The results suggest that diffusion effects played a decisive role in the timing of fertility transition in Belgium. Even after controlling for cultural and socioeconomic changes in space and time, there is a substantial space-time logic of the transition process that remains unexplained – and that is captured by the contagion variable. The models have shown that a given municipality is four to seven times more likely to experience fertility decline if at least one neighbouring municipality has initiated its decline in the previous years, net of structural and cultural evolutions. It is impossible to rule out that the contagion variable might have captured the effect of omitted variables. However, it is highly unlikely that unobserved factors would be so clustered in space and time as to explain away all the positive effect of the contagion variable. All in all, the tests carried out in this chapter allow us to conclude, with a significant amount of certainty, that a diffusion process was at play during the transition, shaping the spread of modern fertility behaviour in space and time.

Apart from diffusion, other factors were shown to have influenced the spatial-temporal patterns of fertility decline. In line with recent studies on the fertility transition (Van Bavel, 2004a; Dribe et al., 2014; Goldstein and Klüsener, 2014), the findings confirm that both structural and cultural factors affected the timing of fertility decline. The 0.5 threshold model yielded more conclusive findings, as it covered a larger territory with a more diverse cultural and socioeconomic landscape. It suggests that the progress of secularisation, literacy and (especially) industrialisation since the end of the nineteenth century accelerated the course of the transition. On the one hand, the rise in education and industrial work would have changed the costs and benefits of childrearing, leading couples to limit their fertility in order to adapt to the new socioeconomic circumstances (Bongaarts and Watkins, 1996; Kirk, 1996) and to achieve social mobility (Eggerickx, 2004). On the other hand, the shift towards secular values would have alleviated the weight of moral control on individuals' choices in respect to birth control (Lesthaeghe and Neels, 2002).

The models also included variables that relate to some extent to the diffusion process within the municipalities.

First, the knowledge of the French language among the population was shown to increase the odds of fertility transition. In particular, Flemish municipalities with more than 10% inhabitants with some knowledge of French were significantly more likely to undergo fertility decline, compared to those with fewer French-speaking residents. This finding adds up to the evidence that new ideas and attitudes towards fertility circulated earlier in the 'Francophone world' (Lesthaeghe, 1977). French-speaking migrants in Flanders would have introduced these new ideas in the local community, as suggested by Van-Bavel's micro-level study in Leuven (Van Bavel, 2004a). Moreover, we can suppose that the members of the Flemish elite, who were often French-speaking, had easier access to information and to the innovative attitudes towards fertility that already circulated in French-speaking areas.

Second, the timing of decline was highly influenced by the population density of municipalities. Social interactions are likely to be more intense in densely populated areas, creating more opportunities for social learning: new ideas about modern fertility behaviour might circulate faster and more freely. What is more, it is possible that moral control weighted less on couples' fertility choices in these areas. It interesting to notice that the latecomers in fertility decline – the Ardennes and the province of Limburg – happen to be the less industrialised areas and also the least densely populated (figure 7.3b). Contrary to the expectations, the proportion of non-native residents in the municipalities was shown to have no impact on the timing of fertility decline. The effect of this variable is explained away by municipalities' population density. These results indicate that, at least at the macro level, the intensity of social interactions are more important than the heterogeneity of social networks in shaping the course of fertility transition.

Another outcome of the models is that, everything else being equal, municipalities' odds of undergoing fertility decline accelerates once the transition process sets off, before slowing down again in the later stages. This is also consistent with the premise of a contagion process, in which 'Change in behaviour stimulates further change' (Montgomery and Casterline, 1993, p 459). As the number of adopters of modern fertility increases over time, the likelihood of adoption also increases.

In conclusion, the event-history analysis with the aggregate dataset gathered for this thesis provides solid evidence that diffusion effects were at play during the Belgian fertility transition, acting as an independent force that shaped the timing and the path of modern fertility behaviour. Furthermore, the analysis revealed the other mechanisms behind the spatial-temporal patterns of fertility decline.

It is nonetheless important to acknowledge some important limitations of the analysis that are inherent to the data. Firstly, the data do not allow to control for the possible diffusion effects coming from beyond the national borders. Belgium is studied here as if it was disconnected from its regional context. Secondly, even though we find evidence of diffusion, it is not possible, from a macro perspective, to clearly distinguish the diffusion mechanisms at play (i.e. social learning and social influence). Finally, macro data were used in order to infer mechanisms that are intrinsically multilevel, involving the impact of macro changes on couples' fertility choices via the intermediate of social interaction (see chapter 1, subsection 1.2.6). The multilevel analysis conducted in the next chapter should offer more detailed insights about the interactions between the fertility transition as a macro process and the individuals' decisions in respect to childbearing.

Chapter 8.

Multilevel contagion model

The descriptive analysis in chapter 6 and the macro-level contagion model in chapter 7 offered solid evidence that diffusion effects were at play during the fertility transition in Belgium. However, these analyses were conducted at the macro level in order to infer mechanisms that are intrinsically multilevel. In fact, diffusion processes involve the interplay between macro-level changes and their outcomes in individuals' decisions by the means of social interaction (Montgomery and Casterline, 1996; Kohler, 2000)[1].

The purpose of this chapter is to investigate the interactions between the macro determinants of the fertility transition and the individuals' response in terms of fertility behaviour. In particular, it aims at examining to what extent the fertility transition as a macro process influenced individual fertility choices, net of the effect of structural and cultural changes.

The analysis is based on the construction of a multilevel logit model with random intercepts for municipalities. The model tests the influence of micro- and macro-level indicators on women's likelihood of stopping childbearing after attaining a given family size. The inclusion of random effects for women's municipality of residence creates a spatial structure in the model and takes into account unobserved spatial factors, producing therefore more accurate results compared to a simple fixed-effects model.

The model is built on micro-level longitudinal data of a selection of women born between 1890 and 1899, who participated in the latter part of the Belgian fertility transition. The individual data, obtained by a retrospective approach from the 1981 Census, are discussed in detail in chapter 4. Moreover, the model contains several of the macro-level indicators used in the macro contagion model. These variables cover different economic, cultural and social networks aspects of municipalities.

The organisation of this chapter is identical to that of chapter 7. Sections 8.1 and 8.2 respectively present the model design and the covariates included in the model. The

[1]See also chapter 1, subsection 1.2.6.

results are shown in section 8.3, followed by a discussion.

8.1. Random-effects logit model

The model used in this chapter is built on the diffusion model conceived by Van Bavel (2004a), which is itself an adaptation of the general causal diffusion model (see chapter 5). Based on longitudinal data compiled from the population registers of the town of Leuven between 1846 and 1910, Van Bavel developed a micro-level logit model in order to investigate the determinants of the adoption of innovative fertility behaviour during the transition.

What Van Bavel (2004a) considers as ‘innovative fertility behaviour’ in the scope of the fertility transition is the parity-dependent (or parity-specific) stopping behaviour. This means that, during the transition, couples are thought to have started to deliberately cease childbearing once they attained their desired number of children. It is still a matter of debate whether fertility control was applied prior to the transition, and evidence suggest that, indeed, couples would limit their fertility under certain circumstances, namely by means of births spacing (Santow, 1995; Van Bavel, 2004b; Bengtsson and Dribe, 2006; Dribe and Scalone, 2010). However, it is commonly accepted that parity-specific stopping behaviour was a true innovation that became increasingly common among the population within the transition process (Van Bavel, 2003; Dribe and Scalone, 2014). In either way, whether or not parity-specific stopping constitutes a true innovation, it is undoubtedly a defining trait of the transition, and it was its expansion that ultimately led overall fertility levels to decline. As discussed in chapter 1, a diffusion process – or a transition process for that matter – does not necessarily involve innovation; it may well concern a marginal behaviour that becomes increasingly widespread.

In practice, Van Bavel (2004a) uses longitudinal data to model parity-specific stopping behaviour within a logit framework. The dependent variable of his model expresses the likelihood that no more child is born within five years after the birth of the previous child (i.e. childbearing stopping after the k-th children is born). The five-year limit is used because there are few births after that interval of time (Van Bavel, 2004a). Moreover, it has the advantage of ruling out unplanned births; for instance, if a couple decided to stop childbearing after the birth of the third child and had a fourth child after ten years, this could indicate that they were already applying a stopping strategy, only ineffectively.

The model is based on a ‘person-birth intervals’ dataset, each individual appearing as many times as the number of births. The parity attained at the beginning of each birth interval is the main control variable (which corresponds to the time variable in a classic event-history model). Other covariates in Van Bavel’s study included individuals’ demographic, socioeconomic and cultural characteristics, as well as information on individuals' social networks. This allowed him to investigate the net impact of diffusion mechanisms on parity-dependent birth limitation[2].

As pointed out in chapters 3 and 4, information on individuals' social networks are not available at the scale of the country. However, Van Bavel's model can be adapted to our data in order to investigate the interactions between the macro determinants of the transition and fertility behaviour at the individual level. To this end, I added a multilevel structure (Luke, 2004) to Van Bavel's logit model, combining micro- and macro-level data and allowing for random effects for municipalities. The model can be represented as follows:

$$\ln\left(\frac{p(Y_{imk})}{1-p(Y_{imk})}\right) = \alpha_k + \boldsymbol{\beta}\boldsymbol{X}_{ik} + \boldsymbol{\gamma}\boldsymbol{Z}_{mk} + \upsilon_{mk} + \varepsilon_{ik} \qquad (8.1)$$

The dependent variable of the model is the logit-transformation of the probability, for woman i residing in municipality m, that no more child is born within five years after the birth of the k-th child (Y_{imk}). On the right-hand side of the equation, the fixed part of the model includes covariates both at the individual and municipal levels. $\boldsymbol{X}_{ik}$ is a set of micro-level variables with demographic and socioeconomic information on individual i at the beginning of the k-th birth interval. The variables set $\boldsymbol{Z}_{mk}$ comprises different indicators at the level of the individual's municipality of residence m; these include demographic, economic and cultural indicators, as well as information on the municipalities' stage in the fertility transition. Finally, the random part of the model is composed of error terms for municipalities (υ_{mk}) and for individuals (ε_{ik}). The decomposition of errors into these two terms creates an hierarchical structure in the equation and allows the intercept to vary according individuals' municipality of residence. This way, the random effects term adds a spatial dimension to the model, taking into account the resemblances in the effect of the different variables on individual behaviour within municipalities. It also controls for unobserved spatial factors that could affect the dependent variable.

As mentioned above, the model is based on a 'person-birth intervals' dataset. Suppose a woman who had three births over her reproductive life course, with intervals between births smaller than five years. The woman will appear three times in the dataset: in her first and second rows, her crude parity is respectively 1 and 2, and the dependent variable takes value 0 because she had not yet stopped childbearing. In the third row, the dependent variables takes value 1 because no more births followed within five years after the birth of the third child. This last interval is said to be 'open', and the woman stopped childbearing after her third child. Macro- and micro-level covariates included in the dataset correspond to the situation at the beginning of each birth interval.

Micro-level longitudinal data were obtained from the 1981 Census. They contains information on reproductive histories and individual characteristics of 7,740 women.

[2]See chapter 1, subsection 1.3.2 for an overview of Van Bavel's (2004a) study and findings.

As a reminder[3], this individual dataset is composed of Belgian women born in Belgium between 1890 and 1899, with complete marriage and at least one child, and who had lived in the same dwelling since the birth of the first child until 1981. These women participated in the latter part of the fertility transition, and their reproductive life unfolded roughly between 1910 and 1940.

The individual dataset presents several potential limitations, as it concerns retrospective information based on very old birth cohorts interviewed in 1981, and it includes only a selection of women who lived in the same dwelling for most of their lives – the only group for which it is possible to determine in which municipality their reproductive life unfolded. In particular, the fertility level of these old cohorts is most likely underestimated, and the group of 'same-dwelling' women is considerably less mobile in space than the average (nearly 70% of them had always lived in the same municipality). Nevertheless, to the extent that our purpose is to investigate diffusion mechanisms, and not to examine overall fertility, the data should still provide interesting insights.

Since the municipality of residence of each women is known, it was possible to link the individual data to the aggregate indicators used in the previous analyses. The time series of macro indicators, however, are limited to 1934, whereas some birth intervals in the individual dataset go beyond this year. The only solution to link micro and macro data was to impose censoring in 1934 (which resulted in the censoring of 1,247 women, who stopped childbearing in later years).

The final 'person-birth intervals' multilevel dataset, based on the 7,740 selected women, has a total of 15,055 birth intervals, from which 4,829 are open (childbearing stopping = 1).

8.2. Covariates

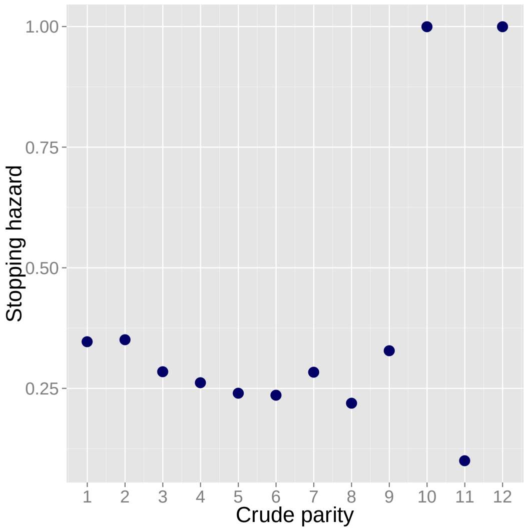
8.2.1. Individual-level variables

The main idea of the logit model used in this chapter is to estimate women's likelihood to stop childbearing as a function of their attained number of children (i.e. parity-dependent stopping behaviour). Therefore, the *crude parity* is a crucial control in the model[4]. This is a time-varying variable that indicates the total number of children attained at the beginning of each birth interval. Figure 8.1 shows childbearing stopping hazards as a function of the crude parity. The graphic indicates a slightly nonlinear

[3] The selection of census data and their limitations are discussed in detail in chapter 4.

[4] Van Bavel's model (2004a) distinguishes crude parity and net parity. The former includes all children born, whereas the latter only takes into account the surviving children. Unfortunately, the 1981 Census data does not allow us to make this distinction because there is no information on infant mortality. However, as it was argued in chapter 4, it is likely that the underestimation of fertility of older birth cohorts is due to the omission of children deceased at younger ages. It this hypothesis holds, we can assume that, in a retrospective approach using old birth cohorts, the crude parity is fairly close to the net parity.

relationship until seven children. After that, stopping hazards seem to take random values because of the small number of women with eight children and more. In order to take into account the nonlinearity and the random variation at higher parities, the crude parity was included in the model as a categorial variable, with values 1, 2, 3, 4, 5, 6 and 7 and more (see table 8.2).



Source: 1981 Population Census

Figure 8.1.: Childbearing stopping hazards by the attained number of children

Age and *marriage duration* are likely to influence women's fecundability (Van Bavel, 2003, 2004a), and must also be included as control variables[5]. Women's age was included as a categorial variable (see table 8.2). Marriage duration is expressed by the number of years between marriage and the beginning of each birth interval. Tests have shown that the effect of marriage duration on stopping is nonlinear, and thus a polynomial term was also included.

Women's *birth cohort* (1890–1894 and 1895–1899) are also controlled for in the model. It is likely that modern fertility behaviour was more widespread among women from the younger cohort, as their reproductive life unfolded during a more advanced stage of the fertility transition.

Finally, individual-level covariates include women's education level in two categories (see chapter 4): low (maximum primary education) and medium-high (higher than

[5]Infant mortality is also likely to influence fertility at the individual level. In his article, Van Bavel (2004a) includes in the model a binary variable that accounts for the death of survival of the last child, which is shown to be significant. Unfortunately, such information is not available in the 1981 Census data.

primary). There are different scenarios in which education could be related to the adoption of modern fertility. First, women with higher education are expected to have easier access to information and broader social networks, and would thus limit their fertility more than low-education women (McDonald, 2000; Mason, 2001). Alternatively, socioeconomic changes could have a greater impact on the fertility behaviour of low-education women, if we assume that they are more economically vulnerable. However, as the two groups of women are fairly homogeneous in respect to their fertility behaviour, the effect of the education variable could have little or no effect on the likelihood to adopt parity-dependent stopping behaviour. Table 8.1 shows the total fertility by education level according to women's place of residence. On the one hand, educational differences in fertility are small in most provinces. On the other hand, there does not seem to be a consistent relationship between fertility and education across the territory. Taking Belgium as a whole, higher-education women have 5.38% lower fertility levels compared to low-education women. The relationship is however inverted in many provinces, whether in Flanders or in Wallonia, no matter their economic and cultural characteristics or their stage in the fertility decline.

Table 8.1.: Total cohort fertility of selected women from the 1981 Census (born between 1890 and 1899, with complete marriage and at least one child) by education level and province of residence

Area	Education level		Difference (%)
	Low	Med-High	(Med-High−Low)/Low
Belgium	2.79	2.64	−5.38
Antwerp	2.60	2.48	−4.62
Brussels	1.73	1.59	−8.09
Flemish Brabant	2.68	2.37	−11.57
Walloon Brabant	1.71	1.82	6.43
West Flanders	2.80	2.67	−4.64
East Flanders	2.61	2.79	6.90
Hainaut	1.55	1.60	3.23
Liege	1.81	1.96	8.29
Limburg	3.84	3.90	1.56
Luxembourg	2.58	3.00	16.28
Namur	1.92	1.97	2.60

Source: 1981 Population Census

8.2.2. Transition timing variables

One of the main interests of the multilevel model in this chapter is to examine the interactions between the fertility transition as a macro process and individual fertility choices. To this end, two time-varying categorial variables were constructed based on municipalities' transition timing.

The first one provides information on the *transition stage in the place of residence*. The variable is built on the municipal marital fertility index (I_g) annual series and the definitions of transition used in chapters 6 and 7. A municipality is considered to be 'pre-transitional' when its I_g level is above 0.7. The 'transition onset' of a municipality corresponds to the moment in which I_g drops by 10% in respect to its initial level, in 1887. Finally, a municipality is considered to have reached an 'advanced stage' in the transition when its I_g level falls below the 0.5 threshold. For each women in the dataset this variable accounts for the transition stage of her municipality of residence at the beginning of each birth interval. This variable can be seen as a within-municipality contagion term[6]. In the multilevel model this contagion variable will allow to test whether the fertility behaviour of the inhabitants of a woman's municipality – who are supposedly part of her social network – influence her own behaviour, net of other factors that are likely to affect fertility. It is expected that the more advanced her place of residence is in the transition process, the more likely she would be to stop childbearing with a lower parity.

A second variable combines information on *migration and transition background*. A first category of this variable assembles 'native' women, i.e. those who reside in the same municipality where they were born. By definition, this category does not vary in time. All the other, non-native women are assigned to the transition stage in the municipality of origin at the beginning of each birth interval. For a given non-native woman i born in municipality m, the variable expresses whether at the beginning of birth interval k her municipality of birth m was 'pre-transitional' ($I_g > 0.7$), had experienced the 'transition onset' (10% I_g drop) or had reached an 'advanced stage' in the transition process ($I_g < 0.5$). Hence, the variable is time-varying for non-native women only.

8.2.3. Macro-level variables

The model includes four macro-level time-varying indicators from the aggregate dataset, which were also used as covariates in the macro contagion model in chapter 7. These indicators refer to the socioeconomic, cultural and networks aspects of women's municipality of residence at the beginning of each birth interval. The same hypotheses

[6]In the macro-level model in chapter 7, the contagion variable tested the influence of neighbouring municipalities on the transition timing – or the 'between-municipality contagion' from a macro perspective. Here, however, the contagion term tests the influence of a woman's social network (represented by the overall behaviour of those living in the same *commune*) on her own fertility choices – i.e. the 'within-municipality contagion' from a multilevel perspective.

discussed for the macro-level model in chapter 7 hold for the multilevel model[7].

The *industrialisation* level of municipalities is measured by the proportion male adult population employed as blue-collar in the industrial sector. This variable is expected to have a positive impact on the likelihood of limiting fertility: industrialisation would have changed the costs and benefits of childbearing and made larger families economically disadvantageous (Bongaarts and Watkins, 1996; Kirk, 1996; Eggerickx, 2004). In other words, women living in highly industrialised municipalities would have higher odds to stop childbearing with lower parity.

The Marriages in Lent index is used as a proxy of the municipalities' *secularisation* level. In municipalities where the secularisation process is still behind, moral and social control is likely to prevent couples to adopt modern fertility behaviour (Lesthaeghe, 1977; Lesthaeghe and Neels, 2002; Eggerickx et al., 2008). On the other hand, as secularisation unfolds, the shift away from traditional beliefs would have made birth control more acceptable. Therefore, the secularisation level in a woman's place of residence is expected to be positively associated with her odds of ceasing childbearing.

The *population density* is a measure of the intensity of social interactions in a municipality. Women living in municipalities where population density is high should have easier access to new ideas and information about modern fertility behaviour, which would in turn increase their odds of childbearing stopping.

Finally, the *proportion non-natives* in a municipality is an indicator of the heterogeneity of social networks. As argued before, new values and attitudes are supposed to flow more easily within heterogeneous networks, or 'weak ties' (Granovetter, 1973). Women living in municipalities with high proportions of non-natives would be more exposed to innovative ideas and examples and would be possibly less influenced by social and moral control. Thus, this variable is expected to be associated with the adoption of stopping behaviour at lower parity levels.

The values of municipal indicators at the beginning of each individual birth interval were taken from the annual time series constructed by interpolation. Industrialisation and secularisation were lagged by one year, whereas population density and the proportion non-natives were included with a five-year lag (see chapter 7).

Table 8.2 brings an overview of the covariates included in the models, as well as their descriptive statistics.

[7]See chapter 3, section 3.3; and chapter 7, section 7.2 for more details on the construction of these indicators and their corresponding hypotheses.

Table 8.2.: Descriptive statistics of covariates in the 'person-birth intervals' dataset

Covariates	% / Mean (St. deviation)	Type
Individual-level variables		
Crude legitimate parity (%)		
1	42.0	Categorial;
2	24.3	time-varying
3	13.8	
4	8.5	
5	5.2	
6	3.2	
7 and +	3.0	
Age (%)		
$<$ 25	12.4	Categorial;
25–29	33.1	time-varying
30–34	35.8	
35–39	16.8	
40+	1.9	
Birth cohort (%)		
1890–1894	30.9	Categorial;
1895–1899	69.1	fixed
Marriage duration	4.5	Numerical;
	(3.6)	time-varying
Education (%)		
Low	89.7	Categorial;
Medium-High	10.3	fixed
Transition timing variables		
Transition stage in place of residence (%)		
Pre-transition ($I_g > 0.7$)	56.9	Categorial;
Transition onset (10% I_g drop)	29.9	time-varying
Advanced stage ($I_g < 0.5$)	13.2	
Migration and transition background (%)		
Natives	67.1	Categorial;
Non-natives; place of birth: pre-transition	20.7	mixed
Non-native, place birth: transition onset	8.3	
Non-native, place birth: advanced stage	3.9	
Macro-level variables		
Industrialisation (% male blue-collar)	38.0	Numerical;
	(12.8)	time-varying
Secularisation (Marriages in Lent index, %)	51.3	Numerical;
	(28.4)	time-varying
Population density (inhabitants per km^2)	405.3	Numerical;
	(1455.3)	time-varying
Proportion non-natives (%)	34.6	Numerical;
	(12.1)	time-varying
Number of birth intervals		
Total	15,055	
Open (no birth within five years)	4,829	

Sources: *Mouvement de la population et de l'état civil* and Population Censuses

8.3. Multilevel analysis

8.3.1. Models computation

To recap, the random-effect logit model designed in this chapter aims at estimating the effect of macro- and micro-level variables on women's likelihood of stopping childbearing after a given parity is attained. The dependent variable is hence the likelihood that no more child is born within five years following the birth of the k-th child.

Seven models were estimated using binomial generalised linear regression with random intercepts for women's municipality of residence. Model 1 includes only individual-level covariates. In Models 2 and 3, the two transition timing variables are respectively added. Next, Model 4 includes all the macro-level variables. Finally, the last three models test the interactions between education level and transition timing (Model 5), industrialisation (Model 6) and secularisation (Model 7).

8.3.2. Results

The results of the random-effects logit models are shown in table 8.3. The table displays the covariates odds ratios, as well as goodness-of-fit parameters. For matters of comparison a null model was computed (not shown in table 8.3) including only the crude parity and the random effects for municipalities. The between-municipality variance of the null model is 0.554 and it has a deviance deviance ($-2LL$) of $17,928$.

Model 1: individual-level variables

Compared to the null model, the inclusion of individual-level variables (Model 1) leads to a 9% decrease in the between-municipality differences in childbearing stopping hazards ($1 - (0.502/0.554) = 0.9$)[8].

Women's crude parity at the beginning of birth intervals has a strong negative effect on the likelihood that yet another child is born. Taking the category 'seven or more children' as reference, the odds of stopping childbearing are significantly higher for each lower parity (except for six children). In an alternative model using the crude parity as numerical variable instead of categorial (not shown), each additional birth increases the odds of stopping by 4% (with $p < 0.01$). These results suggest that the Belgian women born since 1890 were already applying parity-dependent stopping behaviour. In fact, if childbearing stopping was completely independent of the attained number of children, the effect of crude parity in the model would be nonsignificant[9].

[8] Furthermore, regression tests including one micro-level covariate at a time have shown that bivariate effects are nearly identical to the multivariate effects obtained in model 2. Therefore, we can assume that there is no collinearity between individual covariates.

[9] As a comparison, Van Bavel (2004a) analysed much older birth cohorts in the town of Leuven. His findings suggest that parity-dependent stopping was not applied among women born until 1850;

Table 8.3.: Multilevel analysis of women's parity-dependent likelihood of stopping childbearing: logit random-effect regression results

Odds ratios	Model 1	Model 2	Model 3	Model 4
Individual-level variables				
Crude parity (ref = 7+)				
1	23.569***	22.750***	22.316***	21.023***
2	14.988***	14.588***	14.335***	13.735***
3	6.415***	6.313***	6.224***	6.057***
4	3.273***	3.253***	3.227***	3.181***
5	1.885***	1.885***	1.876***	1.860***
6	1.278	1.299	1.286	1.281
Age class (ref = < 25 years old)				
25–29	0.881	0.907	0.922	0.885
30–34	1.151	1.211*	1.244**	1.157
35–39	1.876***	1.993***	2.058***	1.879***
40+	7.725***	8.405***	8.616***	7.656***
Birth cohort (ref = 1890–1894)				
1895–1899	1.182***	1.090	1.093	1.087
Marriage duration	1.582***	1.570***	1.565***	1.560***
Marriage duration-squared	0.988***	0.988***	0.988***	0.987***
Education (ref = Low)				
Medium-High	0.917	0.916	0.912	0.897
Transition timing				
Transition stage in place of residence (ref = Pre-transition ($I_g > 0.7$))				
Transition onset (10% I_g drop)		1.829***	1.784***	1.461***
Advanced stage ($I_g < 0.5$)		3.421***	3.280***	1.918***
Migration and transition background (ref = Native)				
Non-native, place of birth: pre-transition			0.801***	0.786***
Non-native, place birth: transition onset			0.961	0.935
Non-native, place birth: advanced stage			0.995	0.897
Macro-level variables				
Industrialisation (% male blue-collar; scale: 10%)				1.159***
Secularisation (Marriages in Lent index; scale: 10%)				1.055***
Population density (scale: 1.000 inh./km^2)				1.006
Proportion non-natives (scale: 10%)				1.172***
Interactions				
Education × Transition stage (ref = Low education)				
Transition onset (10% I_g drop)				
Advanced stage ($I_g < 0.5$)				
Education × Industrialisation (ref = Low education)				
Education × Secularisation (ref = Low education)				
Models parameters				
Between-municipality variance	0.502	0.247	0.241	0.145
df	16	18	21	25
Deviance ($-2LL$)	16,050	15,872	15,856	15,723
AIC	16,082	15,908	15,898	15,773
BIC	16,204	16,045	16,058	15,963

$***\ p < 0.001$; $**\ p < 0.01$; $*\ p < 0.05$ (two-tailed tests)
Sources: *Mouvement de la population et de l'état civil* and Population Censuses

Table 8.3: Continued

Odds ratios	Model 5	Model 6	Model 7
Individual-level variables			
Crude parity (ref = 7+)			
1	20.932***	20.883***	20.998***
2	13.705***	13.655***	13.706***
3	6.050***	6.017***	6.046***
4	3.183***	3.175***	3.181***
5	1.860***	1.852***	1.855***
6	1.286	1.269	1.271
Age class (ref = < 25 years old)			
25–29	0.887	0.889	0.890
30–34	1.160	1.161*	1.162*
35–39	1.879***	1.884***	1.886***
40+	7.622***	7.592***	7.662***
Birth cohort (ref = 1890–1894)			
1895–1899	1.085	1.082	1.085
Marriage duration	1.558***	1.559***	1.559***
Marriage duration-squared	0.988***	0.987***	0.987***
Education (ref = Low)			
Medium-High	0.877	1.065	1.161
Transition timing			
Transition stage in place of residence (ref = Pre-transition ($I_g > 0.7$))			
Transition onset (10% I_g drop)	1.500***	1.467***	1.466***
Advanced stage ($I_g < 0.5$)	1.898***	1.919***	1.917***
Migration and transition background (ref = Native)			
Non-native, place of birth: pre-transition	0.783***	0.787***	0.785***
Non-native, place birth: transition onset	0.930	0.939	0.933
Non-native, place birth: advanced stage	0.908	0.903	0.907
Macro-level variables			
Industrialisation (% male blue-collar; scale: 10%)	1.159***	1.165***	1.157***
Secularisation (Marriages in Lent index; scale: 10%)	1.055***	1.055***	1.060***
Population density (scale: 1.000 inh./km^2)	1.005	1.006	1.009
Proportion non-natives (scale: 10%)	1.176***	1.171***	1.171***
Interactions			
Education × Transition stage (ref = Low education)			
Transition onset (10% I_g drop)	0.771		
Advanced stage ($I_g < 0.5$)	1.020		
Education × Industrialisation (ref = Low education)		0.959	
Education × Secularisation (ref = Low education)			0.956*
Models parameters			
Between-municipality variance	0.148	0.146	0.144
df	27	26	26
Deviance ($-2LL$)	15,719	15,722	15,719
AIC	15,773	15,774	15,771
BIC	15,979	15,972	15,969

$***\ p < 0.001$; $**\ p < 0.01$; $*\ p < 0.05$ (two-tailed tests)
Sources: *Mouvement de la population et de l'état civil* and Population Censuses

As expected, women's age and marriage duration have a strong impact on stopping hazards. The older the women and the longer they are married the higher the odds of ceasing childbearing. Marriage duration has a concave relationship with the dependent variable, with its effect increasing at lower rates after a certain number of years (the odds ratio of the polynomial term are smaller than 1 and significant).

The odds of stopping childbearing are 18% higher ($p < 0.001$) for women born between 1895 and 1899, compared to the older birth cohort. This corroborates the hypothesis that the younger birth cohort was more influenced by the macro trends of the fertility decline, as their reproductive life unfolded in a more advanced stage of the transition.

The effect of women's education level on the likelihood of stopping childbearing is nonsignificant. Interestingly, in a logit model computed without random effects (not shown) the odds ratio of more educated women (Medium-High) are greater than 1 (but still nonsignificant). Once we add a spatial structure in the model through including random intercepts for municipalities the odds ratio of this category becomes below 1. In fact, taken as a whole the total fertility of more educated women is slightly lower compared to low-education ones; however, this relationship is inverted in many parts of the country (see table 8.1). Either way, the women born in the latter part of the nineteenth century were rather homogeneous in respect to their education level. Very few of them reached a higher level than secondary education. The homogeneity in education and the diversity of educational differences in fertility across the territory might explain the lack of effect of the education variable on childbearing stopping hazards when all Belgian women are taken together in a spatially-structured model.

The effects of individual-level variables change very little when municipal-level variables are taken into account in the subsequent models (2 to 7).

Models 2 and 3: transition timing variables

Model 2 includes the transition stage in the municipality of residence in addition to individual-level covariates. The inclusion of this new variable leads to a substantial decrease in between-municipality differences in stopping hazards: compared to Model 1, the random intercepts variance decreases by 50% (or a 55% decrease compared to the null model). Also, the model fit is significantly improved in respect to Model 1 ($p < 0.001$ for $\Delta{-2LL} = 178$ and $\Delta df = 2$).

As expected, the transition stage of women's place of residence has a strong effect on their likelihood of stopping childbearing. Once a municipality starts its fertility transition (10% I_g drop) the odds of stopping increase by 83% ($p < 0.001$). Reaching an advanced stage of the transition ($I_g < 0.5$) results in three times higher odds of stopping compared to a pre-transitional stage ($p < 0.001$). These results corroborate

only the 1864 generation was shown to stop childbearing as a function of the parity attained.

the hypothesis that the macro process of fertility decline has an impact on individual fertility behaviour. The behaviour of the other people where a woman lives seem to have an influence on her own fertility choices. However, at this point Model 2 does not indicate the net effect of transition timing. Other macro variables that could influence fertility – namely the socioeconomic, demographic and cultural aspects of municipality – are yet to be taken into account.

The effect of the birth cohort variable is explained away by the inclusion of municipalities' transition stage, which gives support to the idea that younger cohorts were more influenced by the advanced stages of the fertility transition.

Model 3 includes further the categorial variable accounting for women's migration and transition background. Compared to women who lived in the same municipality where they were born (natives), non-native women whose place of origin is still in a pre-transitional stage have 20% lower odds of stopping childbearing ($p < 0.001$). However, the onset of fertility decline in non-native's place of birth does lead to different stopping hazards in respect to natives. These findings must be interpreted with caution because of the particular mobility patterns of our sample. As pointed out in chapter 4, the women selected from the 1981 Census are much less mobile than average. It could be that fertility differences between natives and non-natives in the sample do not reflect the overall differences between these groups among all women. Still, the results of Model 3 suggest that the transition stage in migrants' place of origin does influence their fertility behaviour. A possible explanation is that women who were socialised in regions where the transition lay behind would have reproduced the average behaviour of their place of origin. Hence, early socialisation could be an important determinant of future fertility choices independently of the current trends in the place of residence (Kulu, 2005), at least in the specific context of the Belgian fertility transition. It is also interesting to notice that the effect of the transition stage of municipality of residence is weakened in Model 3. This suggests that part of the effect of transition timing is accounted for by women's place of origin, and not only their place of residence.

Model 4: macro-level variables

The inclusion of municipal-level indicators in Model 4 significantly improves the fit in respect to Model 3 ($p < 0.001$ for $\Delta{-2LL} = 133$ and $\Delta df = 4$). Furthermore, the between-municipality differences in childbearing stopping hazards become considerably smaller (-74% compared to the null model and -40% compared to Model 3).

As expected, both the industrialisation and secularisation levels of municipalities have a positive and highly significant effect on women's odds of stopping childbearing. These results are consistent with the hypotheses and with the findings of the macro-level contagion model in chapter 7. The more industrialised the women's place of residence, the more costly an additional child would become. In an industrial context larger families would have become an obstacle to social mobility (Eggerickx, 2004).

Moreover, women living in secularised municipalities are likely to be embedded in a more progressive environment, with liberal attitudes towards birth limitation and weaker moral and social control on individual fertility choices (Lesthaeghe and Neels, 2002; Eggerickx et al., 2008). In summary, in line with recent studies (Van Bavel, 2004a; Breschi et al., 2013, 2014; Dribe and Scalone, 2014; Goldstein and Klüsener, 2014), the model shows that both structural and cultural factors are compatible – rather than competing – explanations of fertility decline.

It appears from Model 4 that a municipality's population density has no significant impact on its inhabitants' likelihood of stopping childbearing, whereas the proportion of non-natives has a strong positive effect (with $p < 0.001$). In reality, the effect of population density is explained away by the inclusion of the proportion of non-natives: when the latter is omitted from the model (not shown) the former becomes highly significant. The model suggests that it is the heterogeneity of social networks, rather than the intensity of social interactions, that increases the odds of stopping childbearing. These findings diverge from those of the macro-level contagion model in chapter 7, in which population density – and not the proportion of non-natives – was shown to accelerate the course of the transition. This indicates that population density (i.e. the intensity of social interactions) operates at the macro level, accelerating the course of the transition as a macro process; in contrast, the proportion of non-natives (i.e. the importance of weak ties) operates at the individual-level only. The more often women are in contact with people from different backgrounds the more likely they are to control their fertility.

After the inclusion of municipal-level indicators the effect of municipalities' stage in the transition process is somewhat weakened. However, it remains positive and highly significant (childbearing stopping odds increase by 46% once the transition starts and by 94% once it reaches an advanced stage). Even after taking into account structural, cultural and networks characteristics of municipalities that are likely to affect individual fertility behaviour, the transition timing in women's place of residence still has a strong effect on their odds of stopping childbearing. The fertility transition as a macro process has a clear association with the individual fertility choices, net of other macro-level factors. This finding adds to the evidence that contagion effects were at play: a woman's fertility choices seem to be influenced by the fertility behaviour of people sharing the same place of residence – who supposedly make up for her social network.

Models 5 to 7: interactions with education

Even though the education variable was shown to be nonsignificant, it is plausible to think that the effect of education might operate in interaction with another variable. For example, one could expect that the impact of municipalities' transition timing on fertility stopping hazards might vary according to women's education level. Similarly, the effect of industrialisation in terms of childbearing costs could be stronger among low-educated women. However, none of these interactions were shown to be significant (Models 5 and 6). A possible explanation is that in the later stage of the fertility transition and the modernisation process, industrialisation and transition timing would no longer have a differential impact on fertility according to women's education level. We would perhaps obtain more conclusive results in earlier stages of the transition, if we could analyse birth cohorts of women whose reproductive life unfolded in the end of the nineteenth century.

Secularisation does have a significant differential impact on fertility behaviour according to women's education level (Model 7). A 10% rise in the municipalities' Marriages in Lent index increases the likelihood of childbearing stopping by 6% among low-educated women ($p < 0.001$) and only by 1.3% among women with medium and high education ($1.060 \times 0.956 = 1.013$; $p < 0.01$). Put differently, the positive impact of secularisation on fertility limitation seems to be stronger among low-educated women. This could be due to the fact that low-educated women were more subjected to moral and social control and the evolution of secularisation at this later stage of the fertility transition would affect this group in particular. More educated women would have already assimilated secular values and attitudes in respect to fertility at that point.

8.4. Discussion

In this chapter a multilevel logit model was designed in order to investigate the impact of macro- and micro-level variables on individuals' odds of stopping childbearing after a given family size was attained. The model was built on the reproductive histories of 7,440 women from the 1981 Census, born between 1890 and 1899, who participated in the latter part of the fertility transition. The micro-level data was linked to macro-level indicators covering cultural, economic and networks aspects of women's municipality of residence. The model allowed for random intercepts by women's municipality, which added a hierarchical/spatial structure to the logit framework. This strategy produces more accurate results compared to a fixed-effect model, because the random effects of municipalities control for unobserved spatial heterogeneity that could affect individual fertility behaviour.

The model has many potential limitations, which are mainly due to the nature of the micro-level data. The retrospective information is based on very old cohorts interviewed in the 1981 Census, whose number of births is possibly underestimated due to memory gaps and to the omission of infant deaths. Among the women present in the 1981, only those who lived in the same dwelling since the birth of the first child were selected for the analysis. In fact, those are the only women whose reproductive life can be situated in space. Although their fertility behaviour does not seem to differ from the others, these women are characterised by much less mobile migration patterns compared to the average (see chapter 4). Moreover, the reproductive life of these women unfolded roughly between 1910 and 1940, which means that the model only covers the latter part of the fertility transition. Finally, even though the census contains information on women's occupation in 1981, it is impossible to determine their socioeconomic status in the past from a retrospective approach. The only socioeconomic information at the micro level that can be used from the census is the women's education level, which is probably a poor indicator of women's social status. In fact, these birth cohorts were fairly homogeneous in terms of education level and the model's results for education were shown to be inconclusive.

Despite all these limitations, the multilevel model still provides very interesting insights on the interplay between the macro determinants of the fertility transition and the individuals' fertility behaviour. In particular, it allows to better understand the mechanisms through which diffusion operated during the Belgian transition.

First of all, it appears from the models that the stage of a given municipality in the fertility transition has an effect on its inhabitants' fertility behaviour. Compared to a pre-transitional stage, a woman's odds of stopping childbearing increases by 46% once her municipality starts fertility decline (according the 10% I_g drop criterion) and by 94% when the municipality reaches an advanced stage of the transition ($I_g < 0.5$), net of the individual and macro factors that are likely to influence fertility. These results can be interpreted as a within-municipality contagion effect: they suggest that women's fertility choices were not made independently from the behaviour of the other inhabitants in her municipality – who presumably make up for her social network. In summary, even after controlling for industrialisation, secularisation and individual characteristics, the course of the fertility transition in space still seems to have an impact on individual behaviour.

Second, another interesting outcome from the models is that the proportion of non-natives in a municipality considerably increases individuals' odds of stopping childbearing, net of other factors. This finding corroborates the hypothesis that diffusion is facilitated in the context of weak ties. We can suppose that a woman living in a municipality with high proportion of non-natives has more heterogeneous social networks. She would be more likely to be contact with people from different backgrounds, with whom their ties are possibly weaker and from whom they might acquire new examples and ideas in respect to fertility. In this context, it is likely that the diffusion of new attitudes towards fertility can flow more easily by the means of social learning.

Social influence also seems to have played an important role in individual fertility choices. The results suggest that the more secularisation is ahead in a woman's municipality the higher her odds of stopping childbearing. In fact, women living in secularised municipalities are likely to be tied to more a progressive social environment with weaker moral and social control on individual fertility choices. What is more, the impact of secularisation on fertility was shown to be especially strong among low-educated women. In fact, it is likely that low-educated women have narrower social networks and were thus more subjected to moral and social control. The progress of secularisation at this later stage of the fertility transition would affect this group in particular, whereas more educated women would have already assimilated progressive attitudes in respect to fertility at that point.

Finally, the results indicate that migrants whose place of origin was still in a pre-transitional stage had lower odds of stopping childbearing compared to native women. These migrants' fertility behaviour was probably influenced by their place of early socialisation, rather than by the overall fertility in their place of residence as adults. It is reasonable to suppose that these women were less connected to the social networks in their new municipalities and hence less exposed to diffusion mechanisms such as social learning.

In conclusion, in combining macro- and micro-level data, the multilevel model designed in this chapter allowed to go a step further in respect to the previous analyses at the macro level. Whereas the macro-level model in chapter 7 demonstrated the importance of between-municipality contagion in the course of the fertility transition, the multilevel model showed that within-municipality contagion was also at play. The fertility transition as a macro process did in fact influence individual fertility behaviour, net of other factors. Furthermore, diffusion within municipalities seems to have been facilitated by the process of social learning in heterogeneous networks and the reduction of social influence brought by secularisation. These findings amount to the evidence that diffusion effects played a decisive role in the Belgian fertility transition.

Conclusion

The main question that has guided this research is whether diffusion effects influenced the *timing*, the *pace* and the *geography* of fertility decline in Belgium. In other words, did social interactions play a role in the spread of modern fertility behaviour since the end of the nineteenth century?

The motivation behind this question lies on the scarce evidence in the literature of the impact of diffusion in fertility transition processes. ‘General’ studies covering a whole country or territory, such as Lesthaeghe’s monograph on Belgium (Lesthaeghe, 1977), have relied on highly aggregated data available at large intervals of time. They have produced therefore only rough evidence of diffusion effects. On the other hand, ‘local’ studies using micro-level data have managed to offer more direct proof of the importance of social networks on fertility behaviour. This was namely the case in the Flemish cities of Leuven (Van Bavel, 2004a) and Ghent (Matthys, 2013). They fail, however, to seize the impact of diffusion on a country’s transition process. In this context, the premise of my research has been to find a compromise between ‘general’ and ‘local’. It should cover the whole Belgian territory, use a high level of spatial and temporal detail and combine macro and micro perspectives.

To this end a great amount of data has been gathered from different sources. First, an aggregate dataset was compiled from the *Mouvement de la population et de l’état civil* and Population Censuses between 1880 and 1935. It contains a range of socioeconomic, cultural and demographic indicators at a fine level of spatial and temporal detail, covering a crucial period of the fertility transition in Belgium. Most of the data were compiled at the level of 645 spatial units (or municipalities). These units correspond to the present municipal division of Belgium but distinguishes the old urban centres from their rural surroundings. In particular, an indicator of marital fertility (I_g) could be computed at this level, year after year between 1887 and 1934. This municipal yearly time series offers an unprecedented detailed view of the Belgian fertility transition process in space and time.

The aggregate indicators were further linked to micro-level retrospective data from the 1981 Census. These longitudinal data contain information on reproductive histories and individual characteristics of a selection of 7,740 women born between 1890 and 1899. Their reproductive life unfolded between 1910 and 1940, that is in the latter part of the fertility transition.

This unique body of data was used in several quantitative analyses. The common point of all the methods I have employed is that they explore fertility decline in a dynamic perspective. They make the most of the temporal and spatial richness of the data in order to assess the *timing* of transition onset among municipalities (defined as a 10% drop in I_g), the *pace* of transition (as I_g falls below 0.5) and the resulting *geographic patterns*.

In the first instance, different statistic tools developed in demography, geography and epidemiology were applied to the I_g annual time series (chapter 6). These tools offered a thorough description of the spatial-temporal patterns of fertility decline among Belgian municipalities with unparalleled precision. Furthermore, two event-history models were developed from classic diffusion frameworks (Erbring and Young, 1979; Casterline, 2001). The first one – 'macro-level contagion model' (chapter 7) – aimed at estimating the contribution of diffusion, socioeconomic and cultural variables on municipalities' likelihood of experiencing fertility decline. In particular, this first model produced net estimations of *between-municipality diffusion*, i.e. the odds that a municipality experiences fertility decline given that a neighbouring municipality has started its decline beforehand. The second one – 'multilevel contagion model' (chapter 8) – investigated the effect of macro and micro determinants on women's likelihood of deliberately stopping childbearing after attaining a certain number of children. It allowed the investigation of the impact of the fertility transition as a macro process on individual fertility behaviour (*within-municipality diffusion*), net of individual and other macro-level factors.

Together, the different analyses carried out in this thesis produced solid evidence that diffusion effects were at play during the Belgian fertility transition. On the one hand, the results globally confirm that the deep cultural and socioeconomic evolutions since the end of the nineteenth century – namely industrialisation and secularisation – determined the striking changes in fertility behaviour. However, the rhythm and the geography of these changes seem to have been influenced by the way people interact with each other.

The descriptive analysis of the marital fertility time series revealed the strikingly contiguous spread of modern fertility behaviour over time. Fertility decline in Belgium first started at the national border with France, where the transition process was way ahead in the nineteenth century. In then gradually propagated among adjoining municipalities in Belgium, year after year, similarly to a contagious process. After the onset, the path of the spread in the course of the transition followed the main industrial and urban axes: first the Walloon industrial axis Charleroi-Namur-Liège and later the northern axes Brussels-Antwerp and Brussels-Ghent-Bruges. It was along these axes that industrialisation and secularisation levels were the highest in the country. But it was also in these zones that opportunities for social interaction were more frequent, due to the high population density, the intensity of spatial mobility and the presence of railways and roads. In contrast, fertility decline took a long time to reach the zones that were disconnected from the industrial axes, where population density was particularly low and situated relatively far from the French border – namely the north-east of Flanders (province of Limburg) and the south-east of Wallonia (Ardennes).

The macro-level contagion model allowed the investigation of the underlying mechanisms of these spatial-temporal patterns of fertility decline. The results suggest that the industrial development and the secularisation process accounted for part of timing and the pace of fertility change in the Belgian municipalities. However, even after controlling for these structural and cultural changes in space and time, there is a substantial space-time logic of the transition that remains unexplained. That was captured by the between-municipality diffusion in the model. All things being equal, a municipality is four times more likely to start its fertility decline if at least one neighbouring municipality has started its decline before, and seven times more likely to reach an advantage stage of the transition if an adjoining municipality has previously reached this stage. In other words, between-municipality diffusion played an important role in the way modern fertility decline spread in Belgium, independently of other factors that influence fertility behaviour. To the extent that people living in neighbouring places are more likely to communicate and interact, these results suggest that social interactions did influence the course of the transition.

The idea that social networks influenced fertility was given further support by the multilevel analyses. The results revealed that the stage in a municipality's fertility transition had an effect on its inhabitants' fertility behaviour, along with the macro-level cultural and economic conditions. *Ceteris paribus*, women's odds of stopping childbearing increased by 46% once the transition set off in the municipality and by 96% once the municipality reached an advanced stage in the decline process. This suggests that a woman's fertility decisions were not made independently of the prevailing conduct in her place of residence. Rather, her choices seem to have been influenced by the behaviour of the other inhabitants of her municipality, who presumably make up for her social interactions. This within-municipality diffusion adds to the between-municipality diffusion as a strong evidence of the importance of social networks in the course of the transition.

The body of data did not allow to investigate in detail the diffusion mechanisms at play in these networks. Even so, the analyses produced interesting insights on how the structure of social networks might have operated in the spread of modern fertility behaviour.

At the macro level it was shown that population density was an important determinant of the timing and pace of the decline. People living in densely populated municipalities had more opportunities for social interactions (Kohler et al., 2001; Goldstein and Klüsener, 2014). We can expect that they had easier access to information about the costs and benefits of childbearing and the moral acceptability of birth control. Not only there was more room for social learning in these areas, but the weight of social and moral control on individual's choices (social influence) was probably lower.

At the individual level the presence of non-native inhabitants in a municipality increased women's likelihood of stopping childbearing. Social learning was probably facilitated in municipalities with heterogeneous networks (Granovetter, 1973). Women in these places would be more often in contact with people from other backgrounds, offering new examples and ideas on reproductive choices.

The linguistic composition of the Belgian population also offered hints on how social networks operated in the transition. While fertility decline rapidly propagated among French-speaking municipalities, the spread was halted at the linguistic border. Until the early twentieth century, the Walloon municipalities situated at the border were already in advanced stage of the transition, while there were still no signs of decline in most of their Dutch-speaking neighbours at the other side of the border. It was not until the 1910s that modern fertility started to penetrate in Flanders. Moreover, the knowledge of the French language among the population in Flanders accelerated the course of the transition. All things being equal, Flemish municipalities with more than 10% inhabitants with some knowledge of French were significantly more likely to experience fertility decline, compared to those with fewer Francophone residents. All these results reinforce the idea that social networks mattered in the transition. Progressive ideas and attitudes towards fertility circulated much earlier in French-speaking networks (Lesthaeghe, 1977). As social interactions at both sides of the linguistic border was scarce because of the language barrier (Lesthaeghe, 1977), these innovative ideas took longer to reach Dutch-speaking communities. At the same time, people in Flanders with some knowledge of French – mostly the members of the elite – would have been more easily connected to long-distance networks and more exposed to progressive ideas. As it was shown for the city of Leuven (Van Bavel, 2004a), the presence of French-speaking migrants in Flemish urban centres would also have contributed to the spread of modern fertility behaviour among the lower classes.

All these findings suggest that diffusion effects did matter in the course of the fertility transition in Belgium alongside structural and cultural changes. But what was precisely the role of diffusion in the process of fertility decline?

It is indisputable that structural and cultural factors were what ultimately determined the changes in fertility behaviour. The impact of these factors have been largely demonstrated in the case of Belgium (Lesthaeghe, 1977; Eggerickx, 2004). The socioeconomic transformations since the nineteenth century deeply altered the costs and benefits of childbearing. Children had fewer opportunities to work as industrialisation and urbanisation unfolded, especially after the interdiction of child labour and the establishment of compulsory education. Large families were increasingly perceived as an obstacle for social mobility. The rising material aspirations of couples in the urban/industrial context, where wage labour prevailed, became incongruent with a large number of children. At the same time, these structural changes were accompanied by an important ideational shift away from traditional and religious values. Birth control became increasingly perceived as morally acceptable. Secularisation lowered therefore the 'social costs' of deliberately stopping childbearing within marriage.

However, it is reasonable to assume that individuals were not immediately aware of the new costs and benefits of childbearing under the changing economic and cultural circumstances (Bongaarts and Watkins, 1996). It is by social interaction and the observation of others that people might have learned about the economic advantages and the moral acceptability of controlling their number of births. In this sense diffusion might have operated as an intermediate agent between the macro factors and their outcomes in terms of individual behaviour (Kohler, 2000). The abstract forces of the new macro conditions could become intelligible to individuals via the exchange with other members of their community, whether by direct conversations or simply by the observation of examples (Montgomery and Casterline, 1996). Hence, even if socioeconomic and cultural factors were direct determinants of fertility decline, the rhythm and the geography of the transition was certainly influenced by the way individuals were connected in space.

The outcome of this interpretation is that individual behaviours are not independent of the behaviours of others. In line with diffusion theories (Montgomery and Casterline, 1996; Casterline, 2001), this thesis provides empirical support to the idea that individuals rely on their social networks in order to gather the relevant information about the costs and benefits of adopting a new behaviour. At the macro level, in the context of long-term societal mutations, social interactions play an important role in the timing, the pace and the geography of change.

The argument rises at least one implication for research: studies of societal change would have a lot to gain in taking into account the organisation of social networks within a community and/or across space. In fact, the causality links between the macro determinants and the individual behaviour are not always straightforward, as they might pass through the channels of diffusion before translating into behavioural change. Dynamic research methods such as event-history frameworks offer a way to capture the interplay between direct determinants and the role of social interactions in the actual adoption of new demographic behaviours.

It is however important to acknowledge some significant limitations of this research.

My intention in this thesis was to investigate the fertility transition process across the whole Belgian territory with as much spatial and temporal detail as possible. In the compilation of spatial data I favoured the municipal level. This meant that the available fertility data does not cover the entire process of fertility transition. The marital fertility time series begins in 1887, when fertility decline had already set off in a considerable part of Wallonia. All that is known about the beginning of the transition in Belgium remains at a higher levels of aggregation in the works of Lesthaeghe (Lesthaeghe, 1977; Lesthaeghe and Neels, 2002) or in local studies of cities and town at the individual level (Oris, 1991; Van Bavel, 2002; Neven, 2003; Eggerickx, 2004). Moreover, in order to create time series over a long period of time I chose to compile the data from the censuses that were consistently reported over the different editions. Very often the preference had to be given to more simple indicators of the socioeconomic conditions in Belgium (see chapter 2).

As for the micro-level data, it was an implausible task in the scope of this thesis to digitise the rich historical data available in the population registers and vital records for the whole country. The only alternative to obtain individual data at the scale of the country was to use the retrospective information contained in the 1981 Census. Nonetheless, the retrospective approach has considerable drawbacks (as discussed in detail in chapters 4 and 8). The main problem is that the census contains little information about migration histories. For most women it is impossible to know for sure where their reproductive life unfolded. The only women whose reproductive life could be located in space were those who lived in the same dwelling from the birth of the first child until the census date. Hence, the data used in the multilevel analyses were highly selected.

The nature of the datasets had two main consequences. Even though the many analyses and tests produced solid evidence of diffusion, it is impossible to rule out that diffusion effects might have been overestimated in the models. Moreover, the data did not allow investigating in detail the mechanisms of diffusion. It is impossible, for example, to disentangle the contributions of social learning and social influence in the diffusion process.

These limitations yield to the interest of systematic efforts to reconstruct historical longitudinal data. In the Netherlands, for instance, a representative sample for different parts of the country has been compiled from historical administrative sources (Mandemakers, 2006). These data allow the deeper study of social networks and demographic behaviour of the past (Bras, 2014). Similar projects using the rich statistic sources available in Belgium would help enlighten the precise mechanisms at play during the fertility transition at the scale of the country, beyond the local context of a city or town.

The most important limitation of the research concerns the nature of diffusion itself. My findings simply show the importance of social interactions on the course of the transition. However, they do not reveal *what* was being diffused. What was it that people talked about and observed in each other? Did it concern the economic costs and benefits of childrearing? Or did it have to do with the moral acceptability of birth limitation? As in most quantitative analyses, especially in historical demography, the content of diffusion remains unclear. The subject of social interactions would only be revealed by a qualitative analysis of letters, texts, etc. In this sense, the exploration of qualitative sources would be highly edifying as a complement of the quantitative research.

Finally, it would be interesting to apply the framework and methods developed in this thesis to the context of the Second Demographic Transition. In fact, the study of diffusion in the rise of cohabitation and divorce in Europe since the 1960s offers many possibilities. On the one hand, administrative data available in many European countries countries would allow the conduction of space-time analyses with very high precision. The surveys conducted in the last decades also offer valuable information, not only about demographic behaviour but also about values and perceptions. On the other hand, the configuration of social networks in space might be radically different today compared to the past because people are connected across longer distances with new technology. As networks grow more complex in recent years the geographic outcomes of diffusion processes might not be as smooth as they were in the historical fertility transition. But they would certainly not be less fascinating.

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