Understanding the Fertility Gap

New Modelling Approaches to Reproductive Decision-Making

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Abstract

The three chapters included in this dissertation aim to improve our understanding of the distance between people's desires regarding the timing and the number of children they want to have and what they finally achieve. The other recurring topic of this dissertation is the attempt to improve the ways in which we model fertility decisions. Chapter 1 uses Sequence Analysis to offer an innovative way of modelling employment instability. In Chapter 2 an agent-based computational approach is applied to the evolution of the mean age at first birth, in which the decisions of couples are a function of their education and their economic (employment) situation but also of the decisions of their friends and the prevailing norms regarding the timing of the transition to adulthood in their society. Instead of focusing on the decision to have a first child, Chapter 3 presents a model that covers the entire reproductive process in an attempt to generate the evolution of the Total Fertility Rate from the bottom-up. The reproductive process is seen here as a hurdle race in which agents move towards their family size target as they navigate a series of obstacles, with a special focus on gender dynamics at the household level.

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Introduction

When I started working on this dissertation a few years back, the theoretical debate about the determinants of low fertility was still intense. The recovery of period fertility had driven the final nail into the coffin of the Second Demographic Transition theory and a number of emerging narratives were competing to become the next dominant framework.

As evidence started to suggest that most developed countries were no longer leading the decline of period fertility rates, the focus shifted from ideational change to the constraints behind the fertility gap. A series of articles started re-visiting the link between economic uncertainty and fertility decisions beginning in the 2000s while others focused on the lack of gender equity or the difficulties to balance work and family life.

Although systematic work on tempo distortions started in the late 1990s, the idea of a fertility reversal was so attractive that most of the debate about contemporary fertility trends has still been based on the evolution of Total Fertility Rates (TFR). Theoretical speculations tried to make sense of the ups and downs of the TFR as if they would represent in some way the decisions of individuals regarding the number of children they wanted to have.

Recent studies however, seem to be making more systematic use of alternative indicators. The picture that emerges from the analysis of cohort measures in most European countries shows a continuous but slow decline followed by a stabilization of fertility levels, a very different path than the marked decline and recuperation showed by the TFR (Sobotka et al., 2016). Nevertheless, the more stable picture painted by cohort indicators and adjusted versions of the TFR presents significant cross-country variation at the level at which countries stabilize.

The latest available data shows two distinct groups of countries, one that has stabilized close to replacement level and another that still shows an important distance between achieved and desired fertility (Rindfuss et al., 2016).

The stabilization of the average *desired* family size around 2 children marks the actual end of the demographic transition, leaving a narrow margin for creative theorization. There is little doubt that most European countries will remain below replacement level, if the average number of desired children is close to 2, it only takes a small proportion of people unable to achieve their goals (by never getting into a union, for example).

The question is *how far* below replacement fertility will be.

In the next years we will likely witness the end of grand, magic-bullet type of narratives and the move towards a more nuanced, more prosaic framework where a number of well-known institutional and cultural factors play some role in the explanation of the fertility gap: The organization of the education system, the housing market, the degree of economic security, gender equity levels, the flexibility of the norms regulating life-course transitions and the set of policies that ease the combination of work and family life.

Methodological developments, on the other hand, offer more exciting prospects. The growth of agent-based computational approaches in demography has been accompanied by a renewed interest on the limitations of the contemporary standard way of producing scientific facts in the discipline.

Statistical Modelling vs. Agent-Based Computational Approaches

According to Burch (2003), the way most demographers produce and assess scientific work is strongly influenced by the ideas of logical empiricism, although this is rarely made explicit. In his view the pervasiveness of these ideas have created a number of dynamics that hamper the development of the discipline, among them, an excessive focus on data collection and the statistical methods to analyze it.

Having applied both statistical modelling (first chapter) and computational modelling (second and third chapters) I believe Burch's critique is right on target. It often seems that demographers have internalized statistical modelling as the only *natural* medium to relate to the "real world".

Agent-Based Modelling (ABM) approaches are still considered experimental. In academic conferences, ABM papers usually feature in sessions which titles start with the words "Modelling" or "Measuring", although there are no session titles starting with the words ”Statistical Modelling".

This is likely a result, in part, of the way statistics are usually approached in social science textbooks and courses. Statistics are usually presented as a series of techniques to help unveil correlations instead of as a series of tools to build, estimate and validate models against empirical data. The modelling aspect is very often neglected, which results in several problems, like the lack of reflection on the structures we impose to our data or an excessive focus on quantification.

Probably the most detrimental result of the current data-driven paradigm is the restriction of what can be approached scientifically to what can be measured and stored in a dataset. Data is used with the objective of providing a better representation of the real world, but having to limit our representations to the observable aspects of the world is too big a price to pay.

An additional limitation of most statistical models is that we often overlook the descriptive nature of the results they provide. Most statistical models "describe what the data look like but not how they came about" (Burch, 2005). The standard quantitative approach tends to shift the emphasis from the understanding of the generating mechanisms of social processes to the identification and quantification of associations between variables.

The consolidation of Agent-Based Computational Modelling (ABCM) can help overcome some of the limitations of the current paradigm. Instead of being concerned with the modelling of a specific dataset, ABCM aims to capture the dynamics of social systems, understanding the mechanisms that lead to the emergence of a particular phenomena.

The growth of ABCM in demography has come hand-in-hand with a call for the adoption of a model-based approach. Such an approach views laws as the product of models more than as products of nature and considers the model, and not the universal law, the device in which scientific knowledge is condensed (Burch, 2003).

Courgeau et al. (2015) view the introduction of ABCM as a potential paradigmatic change in demography, which will represent an upgrade to the multilevel approach. From this perspective, one of the main promises of ABCM is the ability to introduce feedback loops, providing dynamism to the relationship between the micro and macro levels.

Indeed, the popularization of ABCM has implications that go beyond demography. The ability to explicitly model feedback loops allows to represent social action in a way which is compatible to how sociologist like Giddens (1991) or Bourdieu (1977) have imagined solutions to the classic opposition in social theory between agency and structure.

The ability to better represent the complexity of social processes is the advantage of ABCM that has probably received more attention. Another, less discussed advantage of ABCM is the necessary adoption of the individual's perspective. This does not necessarily mean subscribing to methodological individualism, aggregate social constructions (norms, institutions) can play a role in ABCM precisely through the implementation of micro-macro feedback loops. Conversely, it means to force our models to adopt a perspective that squares with how individuals experience the processes studied.

As I started implementing my first agent-based model (second chapter) I struggled to reconcile the agent's perspective with the use of age-specific rates for different processes (e.g. first child, first union). It took me some time to realize where was the source of this tension, until I started my second model (third chapter) for which I dropped the rates and decided to use rules instead, in a more "pure" agent-based modelling tradition.

The tension I was struggling with comes from the fact that having fertility (mortality, etc.) data organized in the form of rates usually serves the purposes of governmental institutions better than those of academic researchers. The idea of age-specific rates, for instance, has no connection whatsoever with how individuals perceive their reproductive process. This contradiction leads to what Wilson and Oeppen (2003) call *reification*, the naturalization of abstract and arbitrary measures which results in a direct identification of the measure with the process that is supposed to represent. In this process we forget the assumptions and limitations of a measure as it becomes one with the process, as when we refer to "Fertility" instead of the Total Fertility Rate (TFR).

The case of fertility is particularly paradigmatic in this regard because, as mentioned earlier, a significant amount of theory and research was produced in relation to the trends described by the TFR, even though it was known for decades that the indicator misrepresents both aggregate fertility levels and the reproductive process at the individual level.

The question posed by Wilson and Oeppen (2003) becomes then specially relevant "Perhaps we might make more progress in our attempts to understand and explain trends in fertility if we examine the phenomenon in ways which come closer to the ways in which the issues present themselves to the 'actors', whose individual behavior generates the aggregate indices of demographic study?".

Over the years a number of researchers have made efforts to produce more organic indicators (Feeney, 1983; Lesthaeghe and Permanyer, 2014, among others), and it is likely that the growth of ABCM will help push things further in that direction. As Van Bavel and Grow (2016) argue, the consolidation of ABM will likely help to finally abandon the "closed" concept of a population, delimited by the political borders and linked to national bookeeping activities, in favor of a more open concept which focuses on the mechanisms that generate social processes, agent's heterogeneity and their interactions in networks.

Moving to a less artificial idea of population and a less artificial way of measuring and modelling means producing demographic models and indicators that have a more direct interpretation in terms of individual behavior. As in the example below pertaining sociological theory, a more direct behavioral foundation allows for a more fluid communication with other disciplines, at least those occupied with individual and collective action as shows the integration of the Theory of Planned Behavior in a good number of agent-based demographic models.

In addition to a more fluid communication with other theoretical ideas, the introduction of ABM concepts in the demographic community has promoted the convergence of different modelling traditions. Most of the models produced recently combine elements of microsimulation, theoretical agent-based approaches, stochastic modelling and network analysis (Bijak, Hilton, Silverman, and Cao, 2013; Murphy, 2003, Willekens, forthcoming). These models take advantage of the flexibility of ABM, which allows for creative theoretical thinking while still being empirically anchored and policy relevant as in the microsimulation tradition.

Outline of the Dissertation

The journey through the next three chapters should help illustrate most of the points made above. Each chapter represents a different modelling approach applied to the same issue: the determinants of fertility decisions.

Chapter 1 discusses economic uncertainty, one of the key determinants of the decision to have a child in contemporary societies. One of the main contributions of the chapter is the use of Sequence Analysis to provide an in depth description of education-labor market trajectories and their evolution over time. The chapter also offers an innovative way of modelling employment instability. Adapting a measure of complexity we obtain a new indicator which takes into account more information from labor market trajectories than do the measures usually used in similar studies.

The use of the entire sequence of states and their duration attempts to acknowledge the dynamic nature of employment instability as it does its treatment as a time-varying covariate. However, the use of a Proportional Hazards model to explore how labor market instability relates to fertility decisions (both tempo and quantum) suffers from some of the limitations mentioned earlier, largely the static nature of its results and the inability to effectively deal with the endogeneity of labor market and fertility decisions (although solutions are explored).

In spite of its limitations the chapter provides useful insights regarding the evolution of labor market trajectories, offers an alternative, and in some ways improved way to model these trajectories and confirms some of the substantive results obtained by previous studies. A version of the chapter was published as a research article in Ciganda (2015).

Chapter 2 starts exploring dynamic modelling. An agent-based computational approach is applied to the evolution of the mean age at first birth, in which the decisions of couples are a function of their education and their economic (employment) situation but also of the decisions of their friends and the prevailing norms regarding the timing of the transition to adulthood in their society. The chapter illustrates how feedback effects can be easily incorporated into ABM. We consider two types in this case: the feedback (also known as multiplier effect) generated by social interaction and the feedback loop between social norms and individual actions.

Strictly speaking the model presented in this chapter is closer to the microsimulation tradition than to the ABM tradition in the sense that it is empirically grounded and all its events are governed by transition rates. As pointed out earlier, the agent perspective and the rate perspective are not easy to reconcile and the model expresses this tension to some extent. Nevertheless the exercise provides important insights regarding the relative role played by different mechanisms during the recent period of sustained increase in the age at the transition to parenthood.

The generation of scenarios shows, for example, that the pace of change in the Mean Age at First Birth (MAFB) is difficult to explain without including the recursive interaction between individual expectations and social norms. In fact both the micro-macro feedback and the multiplier effect of social interaction have a heavier influence than any other factor in our model. A conclusion that could not have been reached by means of a statistical model. The chapter was written in collaboration with Francisco Villavicencio and its results have been published in Ciganda and Villavicencio (2016).

Chapter 3 profits from additional training in the subject of ABM and from my experience with the previous model, overcoming some of its limitations. It is also a more ambitious model, instead of focusing on the decision to have a first child it covers the entire reproductive process in an attempt to model the evolution of the Total Fertility Rate at the macro level.

The reproductive process is seen here as a hurdle race in which agents move towards their family size target as they navigate a series of obstacles: the completion of their education, the economic situation, prevailing norms regarding the ideal family size, forming a union and reconciling different roles (worker vs. mother/father) in coordination with their partners.

On top of the determinants included in Chapter 2 we consider the conflict arising from asymmetric gender preferences. The objective here is to test recent theories that place the move towards greater gender equity as the main driver of the evolution of the TFR.

Earlier in this section we referred to this model as a more “pure” ABM. Indeed, although auxiliary events (union formation, death) are modeled using transition rates, the decision to have a/an additional child depends on the agent’s intention, which is determined by her status with respect to each of the factors mentioned above. However, this is not a deterministic rule of the type “if x do y” as in classic ABM as the intention does not determine the decision directly but the hazard of a probability distribution. This method, introduced in Klabunde et al. (2016) provides less structure than the use of empirical rates but favors a more fluid modelling of the agent’s perspective.

On the side of limitations, there is an inevitable trade off between the model scope and the degree of complexity of each of its main components. The mate search process and the negotiation of preferences are modeled in a very basic manner and are obvious candidates for further elaboration on future versions of the model.

In any case the level of detail in the current version of the model is enough to provide a convincing answer for the problem at hand: identifying the drivers of the shape of period fertility trends since the second half of the 20th century. More exciting than the present form of the model is its potential. At this moment a promising path is to continue the development of some of its components in collaboration with specialists in different areas (labor markets, union formation and dissolution dynamics, gender role dynamics within couples, etc.) to go beyond the specific question explored in this dissertation and use the model as a virtual laboratory in which to explore a variety of different problems that are key to understand contemporary fertility decisions.

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Chapter 1

UNSTABLE WORK HISTORIES AND REPRODUCTIVE DECISIONS

Abstract

The emergence of new evidence suggesting a sign shift in the long-standing negative correlation between prosperity and fertility levels has sparked a renewed interest in understanding the relationship between economic conditions and fertility decisions. In this context, the notion of *uncertainty* has gained relevance in analyses of low fertility. So far, most studies have approached this notion using snapshot indicators such as type of contract or employment situation. However, these types of measures seem to be falling short in capturing what is intrinsically a dynamic process. Our study combines exploratory (Sequence Analysis) with confirmatory (Event History, Logistic Regression) methods to understand the relationship between early life-course uncertainty and the timing and intensity of fertility. We use employment histories from the three available waves of the *Etude des relations familiales et intergenerationnelles (ERFI)*, a panel survey which constitutes the base of the Generations and Gender Survey (GGS) in France. Although France is characterized by strong family policies and high and stable fertility levels, we find that employment instability not only has a

strong and persistent negative effect on the final number of children for both men and women, but also contributes to fertility postponement in the case of men. Regarding the timing of the transition to motherhood, we show how employment instability has a positive influence for women with more traditional views about the division of labor and a negative influence among those with more egalitarian views.

1.1 Introduction

The first decade of the 21st century witnessed the emergence of a new narrative regarding the relationship between living standards and fertility outcomes. It was Myrskylä et al. (2009) which made the strongest, most explicit case for this regime-change hypothesis, showing how the historically negative correlation between development and fertility becomes positive after countries exceed a certain threshold of human development. This conclusion was supported by a series of papers published in the early and early 2000s that showed how the correlation between women's labor force participation and fertility rates across countries had also reversed, and how countries with a higher share of women in the labor force also presented relatively higher fertility rates (Ahn and Mira, 2001; Adsera, 2004; Kohler et al., 2002).

Although evidence of the above-mentioned trends at the micro-level is more ambiguous than at the aggregate level (Matysiak and Vignoli, 2008), the new narrative surrounding economic conditions and family formation seems to have gained a foothold in fertility analyses, which has translated into an increased interest in the constraints and limitations driving fertility decisions in industrialized countries. In this context, the notion of *uncertainty* has become one of the most relevant factors for understanding contemporary family dynamics in the region (Kreyenfeld et al., 2012)

1.2 Literature Review

1.2.1 Economic Uncertainty and Fertility

Until now, the most consistent evidence of a depressing effect has been found using aggregate unemployment rates (Gutiérrez-Domènech, 2008; Adsera, 2011; Kravdal, 2002), although analyses using individual-level data have also found significant effects in the same direction. De la Rica and Iza (2005) argue, for example, that the labor-market reform that introduced flexible employment contracts in 1984 is one of the main reasons why ages-at-first-birth in Spain are among the highest in Europe. Blossfeld et al. (2005) provides extensive macro- and micro-level evidence on how economic uncertainty negatively affects the family formation process, especially in the case of men in male-breadwinner societies with weaker welfare systems.

Although there are clear indications of the effects of economic uncertainty on fertility, studies on the topic have encountered a serious challenge in disentangling income from substitution effects. According to Becker (1981), an increase in household income can produce two opposite effects on the demand for children: an income effect or a substitution effect. Income rises will not only increase the demand for children, but also the indirect costs of forming a family in the form of income and career opportunities that parents have to give up in order to spend time with their children. Therefore, an income effect is observed when the demand for children is positively affected by an increase in income and a substitution effect when the effect is negative.

The inability to distinguish between these two opposing effects partially explains the ambiguity of some of the results found in the literature and also the relatively high frequency of studies reporting "no effects" of unemployment on fertility behaviors (Kravdal, 2002; Kreyenfeld, 2010; Ozcan et al., 2010).

On the other hand, researchers have been more successful in identifying effects when analyzing the dynamics between unemployment and fertility by educational attainment. On the whole, findings have supported the hypothesis that unemployment positively affects the demand for children among lower-skilled women, while it lowers it among women with larger investments in education (Schmitt, 2012; Kreyenfeld, 2010; Gutiérrez-Domènech, 2008; Del Bono et al., 2012).

Another more straightforward approach for disentangling income from substitution effects, consists in establishing a distinction between women in traditional male-breadwinner arrangements and women in dual-earner households. Unfortunately, the information needed to establish this distinction is often missing from surveys, and only a few studies have provided results accounting for the employment status of both members of the couple. These exceptions confirm that substitution effects prevail when women are caregivers (exclusively) while unemployment tends to depress or delay fertility when both members of the household work (Vignoli et al., 2012; Baizán, 2006).

A third limitation of the literature on economic uncertainty and fertility has been a general tendency to identify static measures of employment status (being unemployed or having a fixed-term contract) with employment instability. We consider the idea of instability to be an intrinsically dynamic one. Perceptions of instability are likely to be influenced, not only by our own present situation, but also by information about previous experiences and future prospects.

In fact, a series of hypotheses regarding the effect of unemployment *duration* and *persistence* haven been proposed, but only recently have researchers started to systematically test them.

While Kravdal (2002) hypothesized that the expectation of a longer period of unemployment could have a discouraging effect on women trying to get established in the labor market, Adsera (2004, 2011) argues that high and persistent unemployment will depress or delay childbearing, as it might lead to an unemployment trap. In a similar line Schmitt (2012) interprets the stronger delaying effect of unemployment found in Germany (when compared with the UK) in terms of the 'threat of long-term unemployment' that earlier fertility implies for German women. Although none of these authors test their hypotheses at the individual level, a few recent studies have incorporated information on employment trajectories in an attempt to measure duration and persistence of unemployment.

Ozcan et al. (2010) considered both the *cumulative number of months in unemployment* and the *number of unemployment spells*, but they do not find the hypothesized negative effect in the timing of the transition to parenthood in Germany. Oppositely, the accumulation of unemployment and non-permanent periods of employment proved to be a relevant predictor of fertility timing in the case of France (Pailhé and Solaz, 2012).

Although the results are still ambiguous, these studies represent a movement towards a more refined measure of economic uncertainty. In this paper, we intend to take further steps in that direction.

The novelty of the approach lies in the use of the entire sequence information instead of a single event (or characteristic) and in the consideration of not only the number of transitions in and out of full-time employment but also the *time* spent in these two states. Even though the *cumulative number of months in unemployment* gives a rough measure of the time spent in unemployment, it does not provide any information on how this duration is distributed, which could be a relevant dimension of an employment trajectory. For example, having an exceptional and relatively large unemployment spell at the beginning of the employment career, followed by a stable trajectory of employment, is quite different in terms of its instability from a trajectory which is constantly interrupted by (shorter) spells out of the labor market.

On the other hand, the *number of unemployment spells* provides information about the frequency of interruptions without any detail on their duration. Our measure combines these two approaches by taking into account both the frequency and the duration of unemployment spells. We come back to this point in Section 1.4, but before that we review some of the insights research has produced regarding the destabilization of employment trajectories and regarding the relationship between uncertainty and fertility in France.

1.2.2 Labor-Market Reform and the De-standardization of the Life Course

Life-course research has demonstrated how the sequence of events that comprise individual biographies in contemporary societies has become less stable, more complex and less collectively determined (Settersten Jr et al., 2008; Billari and Liefbroer, 2010). This notion implies that 'traditional' biographies were highly structured by social institutions and characterized by a lower degree of uncertainty.

However, in the long run, this ideal type against which contemporary trajectories are measured was only dominant for a relatively short period of time (Brückner and Mayer, 2005). In fact, Fussell (2006) has shown how, in the case of the United States, the life course became *more* standardized during the first half of the 20th century, thanks to the expansion of primary and secondary education and the regulation of the labor market. After a couple of decades (from the fifties to the seventies) of high institutionalization and standardization, individual biographies started to resemble one another less and less. This increased heterogeneity and complexity was generally interpreted as a result of four major processes originating in the second half of the 20th century: the expansion of tertiary education, the changes in women's roles, the emergence of post-material values and the deregulation/flexibilization of labor markets.

In the 1980s, flexibilization became the keyword for governments and companies looking for a response to increased external competition within the context of a rapid internationalization of markets (Bukodi et al., 2008). Since then, OECD countries have converged and liberalized their rules on Employment Protection Legislation (EPL) which governs the hiring and firing process.

In this context, the European Commission has favored the implementation of the so-called *flexicurity* approach: a combination of low EPL (to allow for market dynamism) with strong employment security (by means of active employment policies and high unemployment benefits). Although the theoretical advantages of this approach are still the subject of debate[1], empirical analyses have shown that in practice, most European countries have introduced labor-market flexibility at the margin, easing the limitations on temporary forms of employment for labor market entrants, while leaving intact the regulation of permanent contracts. The average share of temporary employment as a percentage of the total dependent work for all workers in Europe (EU21) went from 5% in 1980 to 12% in 2012, with a similar increase (albeit from significantly higher levels) in the case of young workers (15-24), from 21% to 42% (OECD Employment Database 2013).

The result of this *partial and targeted* deregulation (Esping-Andersen and Regini, 2000) has been a deepening of the segmentation of labor markets between the so-called *insiders*, unionized workers, who hold permanent (protected) jobs with higher benefits, and the *outsiders*, who spend a large fraction of their working life in precarious, unprotected positions. Young workers are over-represented among those with precarious contracts and the unemployed, and have experienced the greater income losses as inequality increased in OECD countries over the last decades (Esping-Andersen, 2009).

1.2.3 Are Employment Trajectories Really More Unstable?

Hollister (2011) presents an interesting review of the US case, finding consistent evidence of a decline in long-term tenure rates (one of the most commonly used measures) for men in the private sector since the 1980s, but an increase in employment stability for women in the same period. In

[1] for a critique see: Burroni and Keune (2011)

Europe, there is a similar lack of *irrefutable stylized facts* after the publication of several studies since the mid-nineties (Aeberhardt and Marbot, 2013). However, using a 30-year-long employer-employee matched dataset, Aeberhardt and Marbot (2013) shows that, in the case of France, the employment survival rates have decreased since the 1990s.

Along similar lines, Mills and Blossfeld (2006) found that the careers of men in some European countries have remained more stable than expected. However, they also document the increasing economic uncertainty that younger workers face in the labor market, reinforcing the idea of a strong insider/outsider divide (Blossfeld et al., 2005).

1.2.4 The Uncertainty-Fertility Link in France

France is one of the European countries in which is a priori less likely to find strong effects of uncertainty on fertility decisions, given its relatively strong family policies, its relatively smaller obstacles to reconcile family and work and its relatively high and stable fertility rates. According to Toulemon et al. (2008) family policies implemented in the second half of the 20th century are the main reason why the Total Fertility Rate (TFR) has remained at around 2 births per woman in France, while most European countries have seen their fertility rates fall significantly below replacement level.

Along with the services provided by the *crèches* (day nurseries) and *écoles maternelles* (kindergarten) and the right to relatively generous parental leave, French parents can count on a series of in-cash benefits, allowances and tax deductions that substantially reduce the costs of having children. The impact of these tools could be measured not only directly but also indirectly, through the reinforcement of positive attitudes towards families that are visible in the relatively high proportion of people preferring large families and the strong norm against childlessness (Toulemon et al., 2008).

However, and although not as strong as in other contexts, the delaying effects of economic uncertainty on family formation have been found in France. Kieffer et al. (2005) report a delay in first births for women experiencing unemployment, a result that is consistent with Pailhé and Solaz (2012), who also find *timing* effects, but no effects on complete cohort fertility levels.

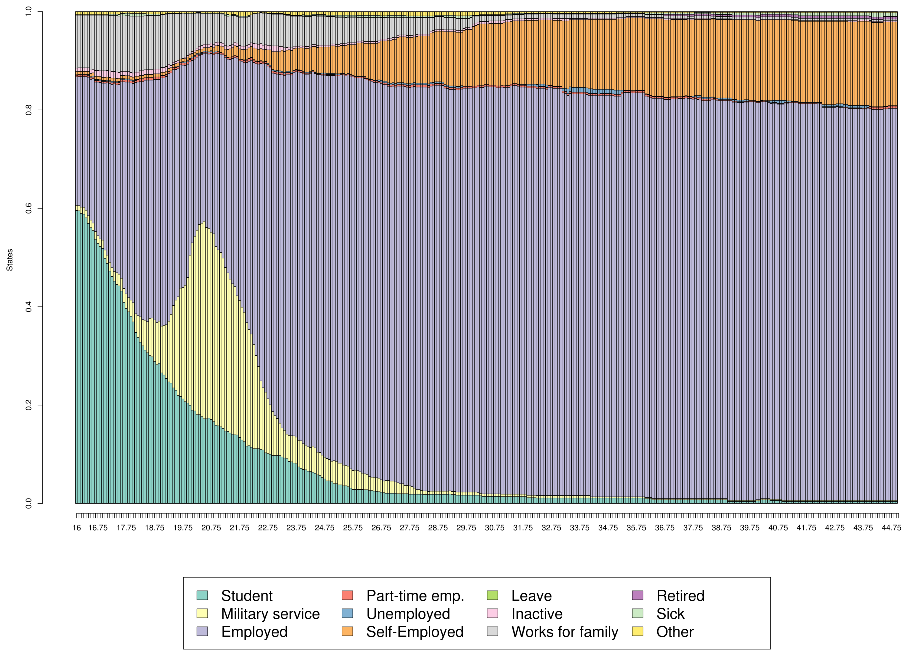
These results suggest that the strength of family policies and programs in France is enough to alleviate but not to completely suppress the effects of economic uncertainty on the family formation process, which is not surprising taking into account the magnitude of the changes in the French labor market.

At the beginning of the 80s, the share of temporary employment on total dependent employment for young workers in France was about 13%, in 2012 it was 55.5%, with negligible differences between men and women (OECD Employment Database 2013). Although it could be argued that this rise might not necessarily mean an increase in the experience of periods of unemployment, especially if workers can jump from temporary contract to temporary contract and from job to job, our first descriptive results suggest otherwise. Figures 1.1 to 1.6 show the proportion of individuals in each labor market/education status at each age for three different cohorts: Those entering the labor market between 1942 and 1961 (born between 1926-45). Those that entered from 1962 to 1979 (born between 1946-63) and from

1980 to 1998 (born between 1964-82) [2].

As expected the *inactive* state covers a large proportion of women's trajectories in the oldest cohort (Figure 1.2) while it is marginal in the case of men (Figure 1.1). Another interesting element to notice is the clear delimitation of the *military service* period, which indicates a relatively high degree of accuracy in the data.

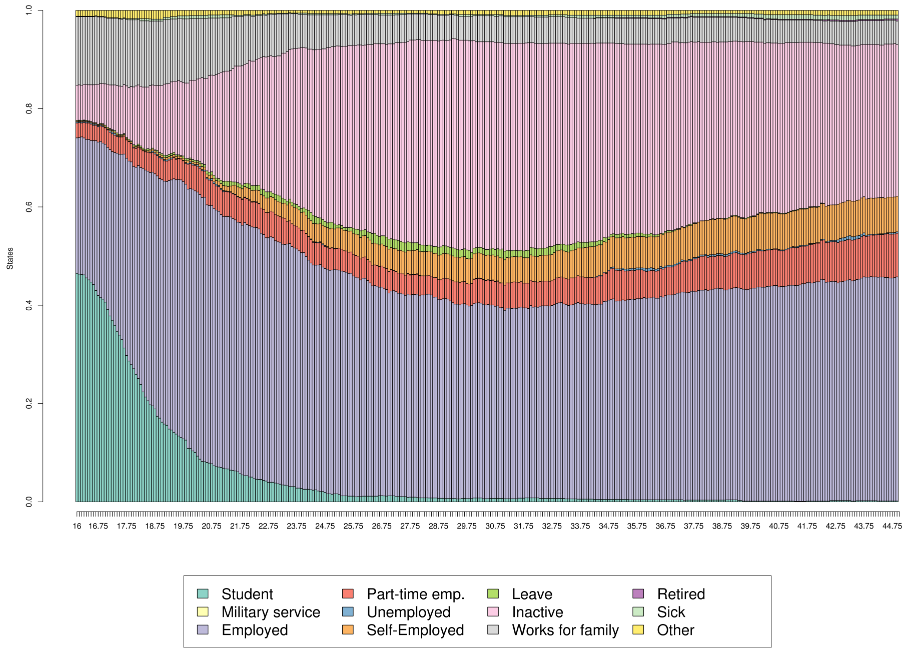
Figure 1.1: Education-Employment trajectories Men 1942-1961 (born 1926-45) | France



The most prominent feature of the trajectories of the second cohort is the high degree of stability of men's trajectories. States other than *employed* or *self-employed* are infrequent. At the same time we see a convergence of the trajectories of men and women, although women's careers

[2]These figures were created by the author from the ERFI data used in the rest of the analyses in this paper

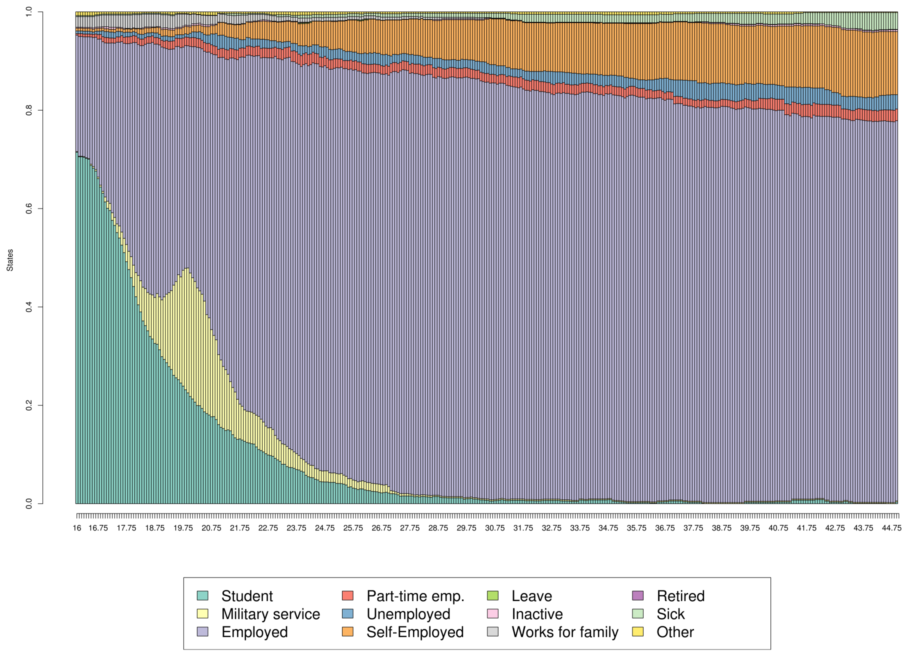
Figure 1.2: Education-Employment trajectories Women 1942-1961 (born 1926-45) | France



still present a higher proportion of *part-time employment* and *inactivity*.

The trajectories of most recent cohorts (Figures 1.5 & 1.6) show that at least part of the deregulation process has translated into a higher frequency of *unemployment* and *part-time employment* spells for both men and women. It is also interesting to note that most of the increase in the mentioned states is concentrated at the beginning of the employment trajectory, supporting previous findings which have shown particularly strong effects for labor market entrants (Aeberhardt and Marbot, 2013).

Figure 1.3: Education-Employment trajectories Men 1962-1979 (born 1946-63) | France

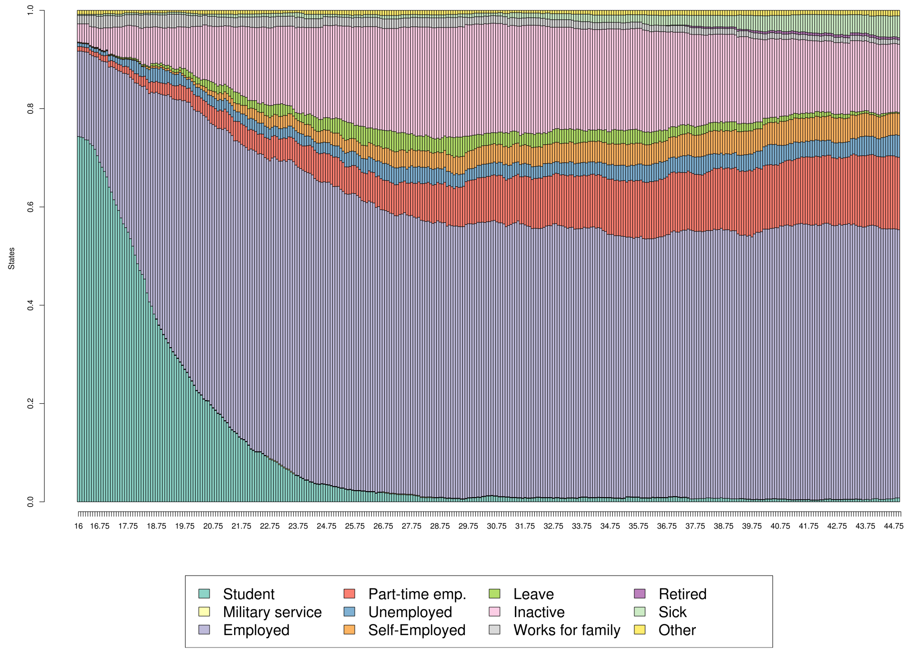


1.3 Questions and hypotheses

In the previous section, we provided descriptive evidence that supports the claim that men's and women's employment trajectories have become increasingly volatile over time. The main question that we will try to answer now is whether this increased instability has an effect on the timing and the intensity of fertility.

As long as the male-breadwinner is still the norm, the neoclassical framework discussed before predicts strong negative effects for men and positive effects for women. It is likely that part of the reduction in fertility for men occurs indirectly, through partnership formation. Men with a weaker commitment to the labor market might be perceived as less reliable

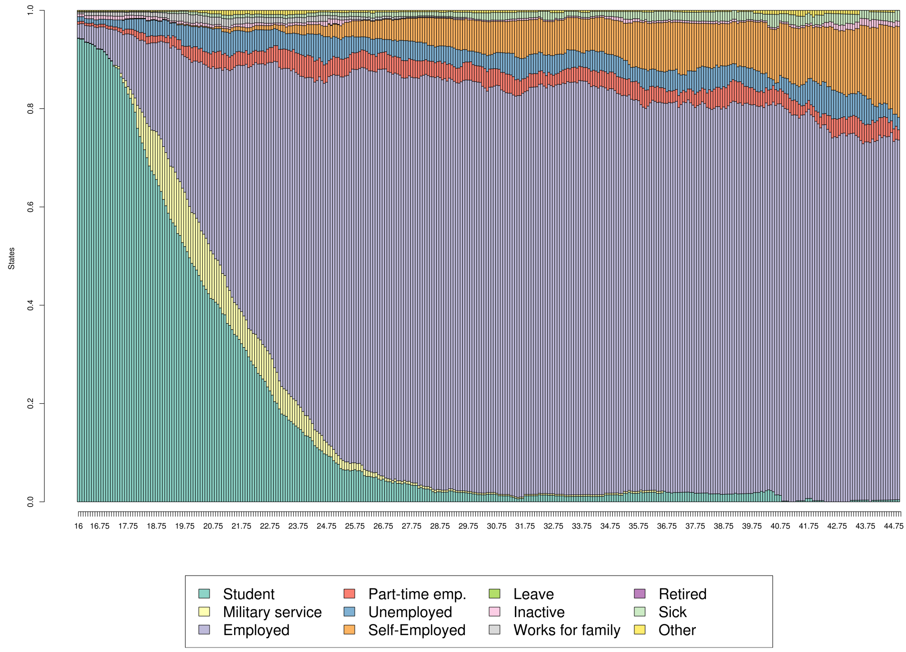
Figure 1.4: Education-Employment trajectories Women 1962-1979 (born 1946-63) | France



candidates for the formation of a family, if, again, the male-breadwinner is still the norm (Kravdal, 2002). Although this is still largely the case, for a country like France where an increasing number of households depend equally on the contribution of both men and women, the expectations from these models need to be specified.

In addition, we have to take into account that our measure of employment instability provides a summary of both duration and persistence in unemployment, and therefore our hypothesis should relate to the mid-to-long-term perspective. Here we have to go back to the 'discouragement' vs 'unemployment trap' debate. The first perspective proposes that long-term unemployment might discourage women from having a strong attachment

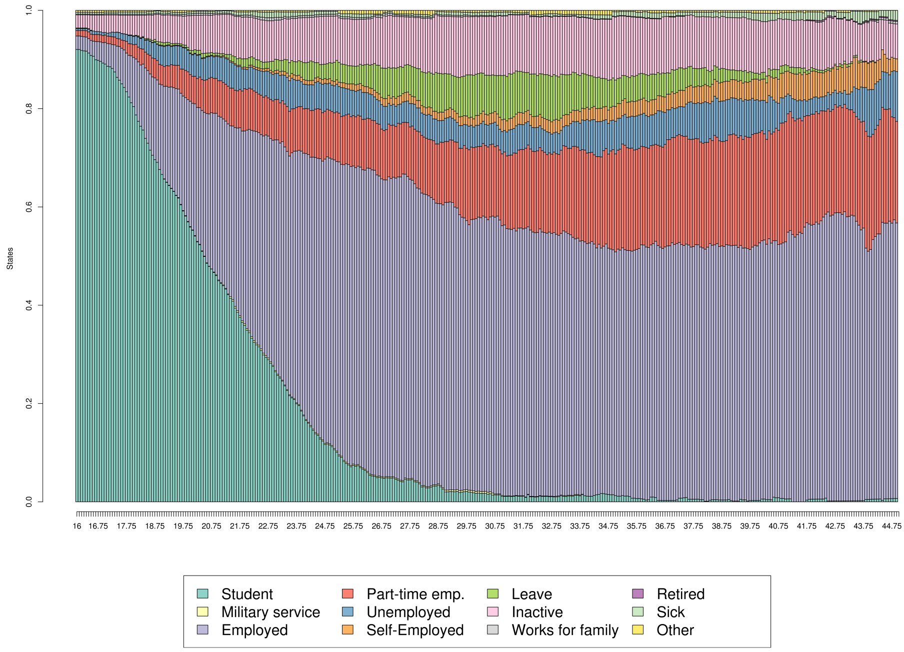
Figure 1.5: Education-Employment trajectories Men 1980-1998 (born 1964-82) | France



to the labor market, making substitution effects emerge (Kravdal, 2002), while the second perspective highlights the enhanced need to postpone childbearing when the threat of staying on the margins of the labor market becomes more visible Adsera (2004, 2011).

As Ozcan et al. (2010) we believe that these two perspectives need not be contradictory but complementary, with each one explaining the reactions to instability of different sub-populations. It is likely that the discouragement effect will emerge faster among women who will accept a male-breadwinner arrangement or who have the option to have a looser attachment to the labor market. For women with a breadwinner role, a more unstable attachment will more directly result in a reduction in their

Figure 1.6: Education-Employment trajectories Women 1980-1998 (born 1964-82) | France



probabilities of forming a family since they will tend to postpone or forgo fertility before they have the opportunity to land a position that matches their aspirations and training. Nevertheless, these types of preferences are not necessarily fixed over the life course and neither is the material possibilities of prioritizing unpaid work within the household, which further complicates the specification of the direction of the effects among women.

For men the dynamics are supposed to be more straightforward. Failing to reach a stable and protected position at the core of the labor market should discourage fertility directly and indirectly (through union formation dynamics) for all education groups.

Finally, we need to consider the institutional and cultural context in

France, where the norm against remaining childless is still strong and where part of the costs of childrearing are absorbed by the state due to strong family policies.

Taking all this into account our hypotheses are:

H1: In the case of men, unstable employment trajectories will be associated with a higher age at first birth, a higher probability of remaining childless and a lower probability of achieving higher-order parities.

H2: Among women, the effects of an unstable employment trajectory will be more disruptive for those less likely to conform to a male-breadwinner arrangement.

1.4 Data and Methods

1.4.1 Data

Our study combines exploratory (Sequence Analysis) with confirmatory (Event History, Logistic Regression) methods to understand the relationship between early life-course uncertainty and the timing and intensity of fertility in France. It takes advantage of the recent availability of complete employment histories in the *Etude des relations familiales et intergenerationnelles (ERFI)* a panel survey carried out by INED and INSEE which constitutes the base of the Generations and Gender Survey (GGS) in France. The panel includes a sample of 18 to 79-year-old residents of metropolitan France. It contains not only detailed information on the reproductive history and fertility intentions of the interviewees, but also complete retrospective and prospective education/employment trajectories.

The first wave was carried out in 2005 including 10,079 men and women and it is representative of the French population. The second wave from 2008 has 6,534 cases and the third one from 2011 has 5,781, (5,433 of whom also participated in the second wave and could then be integrated into our sample, given that the employment histories started to be collected from wave 2).

Our final sample consists then of 6,492 individuals aged 20 to 85, 5,402 of whom participated in the three waves and 1,090 in the first two. Due to the subsequent reduction of the sample, the data is only representative of the 2005 French population after applying the weights that correct for attrition in the subsequent waves, which were used in all our analyses.

1.4.2 Outline of the study

In the first section, we use sequence analysis techniques to quantify the degree of instability of employment trajectories. Sequence Analysis consists of a set of techniques originally developed by molecular biologists to find similar DNA patterns, introduced into the social sciences in the 1980s. These techniques are particularly useful for the study of life-courses because they provide a holistic understanding of individual trajectories, allowing for the combination of multiple dimensions of a biography in one sequence, which becomes the main unit of analysis.

For our analysis, the education/employment histories are combined to obtain a unique binary sequence for each observation in the sample. In ERFI, respondents are asked to provide information about the duration of each spell (of at least three months) in which they were: employed, in school, inactive, unemployed, etc. When respondents were simultaneously in two or more states (employed and studying for example), they were asked to choose the activity in which they spent most time. The possible states in the employment/education dimension are:

Student; Military Service; Employed; Self Employed; Part-Time Employed; On Leave; Help at home; Unemployed; Retired; Inactive; Sick; Other.

These sequence-states were reclassified in order to obtain the above-mentioned binary trajectories that represent the transitions from a state of *stability* to one of *instability* and vice versa. In the case of men, the states included in the stable state are: *Student; Military Service; Employed; Self Employed; On Leave; Help at home; Retired; Inactive; Sick; Other.* While for men *Part-Time Employed and Unemployed* comprise the unstable state, for women, however, we include only unemployment spells as instability given the fact that in a large number of cases, part-time work is related to a decision of the individual or the household and not to an imposition of the labor market. In fact, the data used here shows that men working part-time are approximately one-fifth of the number of women with that type of work. Besides this, 70% of these men are doing it involuntarily, while in the case of women, the figure is about 50%.

States like *Sick* or *Inactive* are considered in the stable category given that we are trying to capture *involuntary* and *indefinite* spells out of the labor market. The case of inactivity is particularly relevant since its inclusion as a form of instability would have enhanced the problems of reverse causality between labor-market attachment and childbearing.

1.4.3 Software

Analyses were performed using R (Team et al., 2005). The Traminer package (Gabadinho et al., 2011) was used for Sequence Analysis and packages Survival (Therneau, 1999) and EHA (Broström, 2009) for Survival Analysis. All of them available at: http://cran.r-project.org/.

1.4.4 Definition of Instability

The measure of instability developed here is an adaptation of the *Complexity* indicator presented in Elzinga (2010), previously called *turbulence* (Elzinga and Liefbroer, 2007), which was developed to measure the uncertainty of sequences of equal length composed of multiple states. In our case, we have binary sequences (two possible states) and sequences of different length (different ages at first birth, censored observations). Therefore, the definition of instability of a given sequence x is:

$$I(x) = log_2 \left(\Phi(x) \frac{s_t^2, max + 1}{s_t^2 + 1} \right)$$

One important advantage of this indicator is that it considers not only the variation coming from number of state-changes in the trajectory but also the differences in the durations of each state. The former is captured through Φ which represents the number of sub-sequences[3] in each sequence. Accounting for the number of sub-sequences we obtain an increasing $I(x)$ as the number of transitions between states increases.

[3] A sequence *z* is a sub-sequence of a another sequence *x* if all the states of *z* appear in x and in the same order. The empty sequence is counted as a sub-sequence, hence the sequence *a-b-a* has 7 sub-sequences: a,b, ab, ba, aba, aa, + the empty sequence.

The second part of the formula captures variation coming from the duration of each spell by dividing the maximum potential variance given the number of states in the sequence (s_t^2, max) over the observed variance of the times spent at each state in the sequence (s_t^2) [4]. The logic here is that the smaller the variance of the time spent at each state (s_t^2) the more difficult it is to predict in which state the individual is going to be at any particular time, hence the higher the instability. This is a particularly interesting property if we consider that instability might come from experiencing continuous periods out of the labor market or a fewer number of periods but of longer duration.

The maximum variance is given by $(d-1)(1-\bar{t})^2$, where *d* is the number of different states in the sequence[5] and $\bar{t}$ the mean consecutive time spent in each state.

The binary logarithm is taken instead of the original quantity, given the large increase in Φ produced by each additional transition between states.

In order to deal with the different lengths of the sequences in our sample, state-durations[6] were standardized by sequence length, expressing the length of each duration in *x* as a percentage of the total length of *x*.

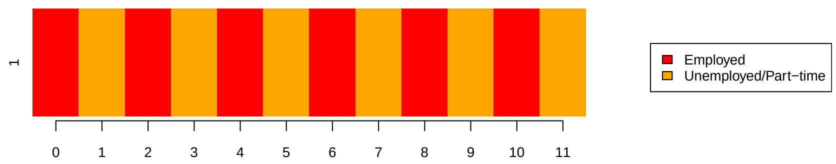
According to this definition, an individual that experiences a relatively small number of transitions between states, but who spends a similar amount of time in the two states will be considered to have an unstable trajectory. Let us consider the two following sequences:

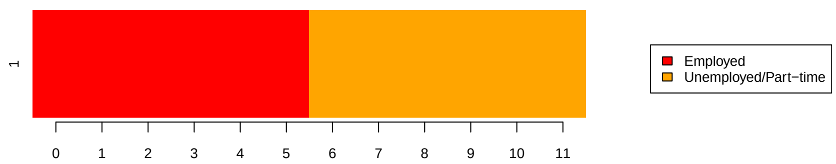
---

[4]Here, one of the main differences is with the Complexity measure, which considers the variance of *state-durations*

[5]Unlike in the case of Complexity (Turbulence in TraMineR) which defines *d* as the number of non-consecutive states/the number of state-durations

[6]State-durations represent the amount of time spent in each non-consecutive state. The sequence: a-a-a-b-b-b-b has 2 state-durations, one of length 3 and one of length 4.





The first hypothetical sequence a is highly unstable, and has 11 transitions (609 sub-sequences) and no variance in the time spent at each state. The second b, has only 1 transition (4 sub-sequences), which means this sequence will be considered as being fairly stable if we were only counting spells. Our measure, however, by accounting also for the variance in the time spent in each state, gives $I(a) = 19.5$ and $I(b) = 12.2$, a is still more unstable than b, but b will still be considered highly unstable given that half of the total length in this trajectory was spent in unemployment.

1.4.5 Classification of Trajectories

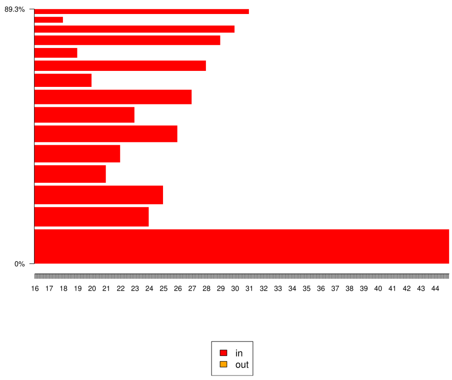
In this section, we assess the performance of our measure in classifying individual trajectories according to their instability level. Although the measure obtained is continuous, we decided to re-categorize it in three levels: Low, Medium and High Instability. Figure 1.7 presents the fifteen most representative sequences for each of the groups, for females. The height of each bar indicates the number of sequences in the group that each of these sequences represent. The percentage in the x-axis is the total proportion of sequences within each group that these fifteen trajectories represent.

The group of *Low Instability* is composed of sequences with scores between 0 and 1, the most representative sequences here represent no unemployment / part-time employment spells and they only differ by their length. Together, they represent 89% of the trajectories in the group, which is the larger part of the female sample since this is by far the category with more cases (n=3099).

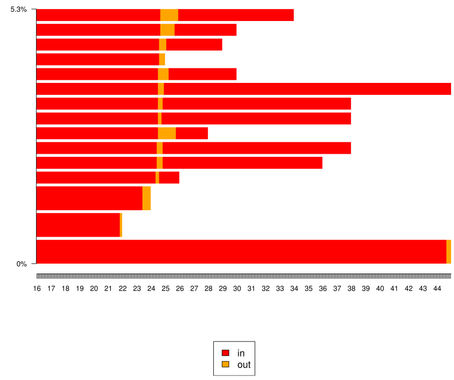
The sequences in the *Med Instability* category (n=340) have a score between 1 and 1.1. Most trajectories here present one relatively brief period of unemployment/part-time employment, which in general starts around age 23-25, probably coinciding with the end of formal education. These periods are labeled *out*, as in a transition out of a state of stability and depicted in orange in the graphs. The total proportion of sequences in the group represented by these fifteen trajectories is significantly smaller than in the previous case, which is not surprising considering this group is composed by more complex trajectories. Substantively, we do not consider these careers to be significantly different than those with low Instability, as it is unlikely that a brief unemployment period will have a dramatic impact on other life-course transitions – so for the reminder of the paper, we decide to collapse these two categories into one and to have it as a reference for analysis.

The group of *High Instability* (n=288) corresponds to sequences with a score between 1.1 and the maximum instability observed in the group (21.9). These trajectories are characterized by multiple transitions and/or long spells of unemployment and, in contrast to the two previous groups, they represent a real departure from a ‘normal’ (or normative) career, and we therefore focus on these individuals in the following analyses.

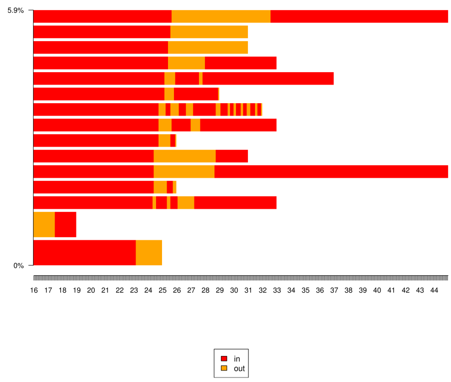
Figure 1.7: Initial 15 Sequences by Instability Level |Females



(a) Low Instability



(b) Medium Instability



(c) High Instability

In Figure 1.8 we present the most unstable sequences for men and women to give the reader an idea of what highly turbulent trajectories look like. The most unstable trajectory among females presents 8 unemployment spells in 17 years (from age 16 to age 33) while the most turbulent trajectory among men has 7 unemployment/part time spells. In the second case the out spells are longer as well as the trajectory, which goes from age 16 to age 43.

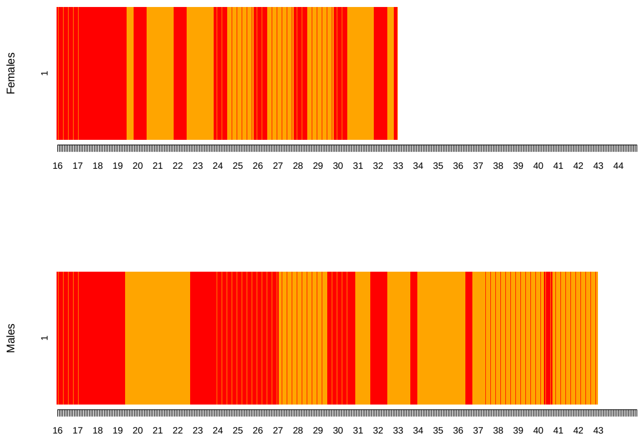


Figure 1.8: Most Unstable Sequences for Males and Females

1.4.6 Event History Models

After trajectories are classified according to their level of instability, the new variable obtained is introduced as a time-varying covariate in a Cox Regression Model predicting the timing of first births. Instability is computed for each trajectory up to the last complete year of age before the first birth and up to age 45 / age censored for those that have not experienced the event. The measure is taken cumulatively (computed over the entire trajectory to that point) at each age, from age 16, and introduced as a binary variable identifying those with *high* vs those with *medium* and *low* instability.

Separate models for males and females are presented, both including individuals from age 20+. In the models we control for the age at which respondents finished/dropped out of school, which is introduced as a binary variable: up to age 18 / after age 18. The effect of education is modeled in this way assuming that the stronger differences in terms of the risk of a first birth are given by the pursuit of tertiary education. Taking into account our descriptive results in Section 1.2.2, we also control by cohort, distinguishing those born between 1976-1986, 1956-1975 and before 1955. Finally, to capture the direct effect of instability on the timing of fertility, we control for the experience of a union, introduced as a time-varying covariate with values 0 before and 1 after the first cohabitation experience.

Given that we are also interested in comparing the performance of our measure against other common measures, we create a time-varying indicator of the employment status (in/out as defined in the instability measure) at each age, which we include as a control in our original model. We also create two time-varying trajectory variables: the cumulative number of spells out of full-time employment at each age and the cumulative number of months/years out of full-time employment at each age, although we compare these in separate models.

In the case of females, we also obtain separate models for women with a more conservative view of gender values and women with more egalitarian perspectives. These indicators were built from a question about giving priority to men when jobs are scarce. Although it has its limitations, it was the best of the few alternatives we had to try to separate women with different priorities regarding their attachment to the labor market and therefore testing the ‘unemployment trap’ vs ‘discouragement’ hypothesis presented earlier.

Our final model is defined as follows:

$$h^{sex}(t,x) = h_0(t) * exp(x\beta_{Instability} + x\beta_{Edu} + x\beta_{Cohort} + x\beta_{Partner}) \quad (1.1)$$

1.4.7 Completed Fertility

To analyze the effects of employment instability on the intensity of fertility at the end of the reproductive period, we run a series of logistic regressions for which the outcome is the parity achieved by respondents at age 45: 0 vs 1+ children, 1- vs 2+, 2- vs 3+ and 3- vs 4+ children. In this case we consider the instability until the age of first birth or until age 45 for those with no children.

We run models for each binary outcome and sex for a sample of age 45+, and we include the following controls:

* Age at finish/complete education (defined in the same way as in the Cox models).

* Nationality: European vs. Other.

1.5 Results

1.5.1 Effects of Employment Instability on Fertility Timing

One of the main arguments presented in this paper is that a measure of employment instability over trajectories will perform better in predicting the timing of the transition to parenthood than a measure of employment status at a single point in time. Tables 1.1 and 1.2 provide some evidence in support of this claim. The first model shows that the time-varying indicator of employment status (see Section 1.4 for a description of the variables) has a negative effect on the hazard of having a first child when other factors are not considered. However, this coefficient loses its significance after we include our control variables. On the other hand, the effect of instability is robust to different specifications of the model. In our data, being unemployed or part time employed does not result in a lower risk of becoming a father, but *a history* of unemployment / part-time employment does.

Table 1.1: Cox Proportional Hazard Model Estimates, First Child, Model with Unemployment — Males

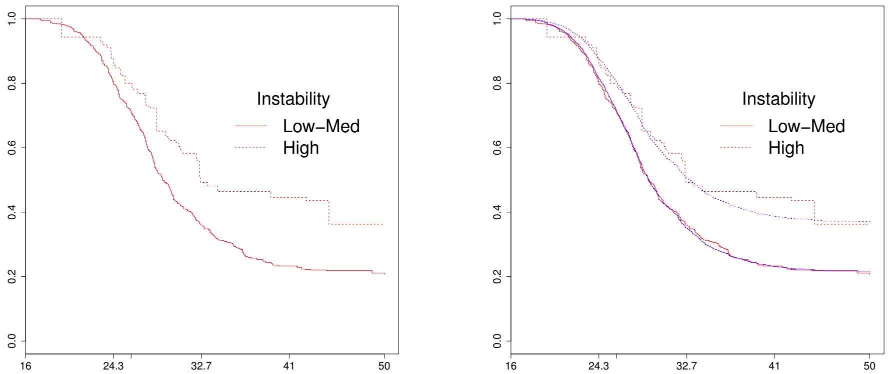
	Dependent variable:		
	First Birth Timing		
	(1)	(2)	(3)
Employed (Ref.)			
Unemployed (TV)	0.714*	0.760	0.915
	(0.179)	(0.179)	(0.180)
Age Ends Education $\leqslant$ 17 (Ref.)			
Age Ends Education >18		0.837***	0.864***
		(0.047)	(0.047)
Born 1976 - 1986 (Ref.)			
Born 1956 - 1976		1.103	1.302***
		(0.074)	(0.074)
Born < 1956		1.217***	1.452***
		(0.076)	(0.076)
Ever had Partner (TV)			15.871***
			(0.112)
Observations	40,808	40,808	40,808
Note:	*p<0.1; **p<0.05; ***p<0.01		

It is worth noting, however, how the effect of high instability decreases after we control for the existence of a cohabiting partner, showing that a sizable part of this effect on fertility timing is indirect, through partnership formation. The direct effect is still substantial and having a highly unstable employment trajectory reduces the risk of having a first child by around 20% at each age. The effects of our control variables -education level, cohort and having a cohabiting partner- all go in the expected direction.

Table 1.2: Cox Proportional Hazard Model Estimates, First Child, Model with Instability — Males

	Dependent variable:		
	First Birth Timing		
	(1)	(2)	(3)
High Instability (TV)	0.617***	0.649***	0.814**
	(0.116)	(0.102)	(0.102)
Age Ends Education ⩽ 17 (Ref.)			
Age Ends Education >18		0.819***	0.857***
		(0.047)	(0.047)
Born 1976 - 1986 (Ref.)			
Born 1956 - 1976		1.108	1.297***
		(0.074)	(0.074)
Born < 1956		1.177**	1.424***
		(0.076)	(0.076)
Ever had Partner (TV)			15.770***
			(0.112)
Observations	40,808	40,808	40,808
Note:	*p<0.1; **p<0.05; ***p<0.01		

Figure 1.9 shows the observed and fitted survival curves by instability level for men born between 1956-1976 who left education before the age of 18. As concluded from the model results, those with unstable trajectories have a lower risk of having a first child at each age, more precisely a 35% less risk than those with low-medium instability (model 2, Table 1.2)



(a) Observed (b) Observed + Fitted

Figure 1.9: Observed and Fitted Survival Curves by Instability Level - Males, Born 1956-1976, Age End Edu <18.

Even though our instability measure outperforms the usual employment status measure, the question remains how it compares against other trajectory measures, such as the number of unemployment/part-time employment spells or the cumulative number of months out of full-time employment.

Given the high degree of skewness of its distribution and the lack of familiarity with its metric, we favor a categorical treatment of the instability measure as presented above. However, we use a continuous version here given the continuous character of the other variables. In any case, given their different metrics we cannot offer an exact comparison, as can be seen in Table 1.3 an increase in one point in our instability score produces identical reductions in the risk of having a first child as a twelve-month increase in the duration out of the labor market (regardless of how they are distributed) or an additional unemployment spell (regardless of its length). Analyses with categorical versions of these variables provided similar results (omitted).

Table 1.3: Cox Proportional Hazard Model Estimates, First Child — Males

	Dependent variable:		
	First Birth Timing		
	(1)	(2)	(3)
Cumulative instability *(tv)*	0.880***		
	(0.039)		
Cumulative number of Out spells *(tv)*		0.875***	
		(0.042)	
Cumulative duration of Out spells *(tv)*			0.880***
			(0.030)
Age Ends Education $\leqslant$ 17 (Ref.)			
Age Ends Education $>$ 18	0.825***	0.825***	0.818***
	(0.047)	(0.047)	(0.047)
Born 1976 - 1986 (Ref.)			
Born 1956 - 1976	1.106	1.106	1.122
	(0.074)	(0.074)	(0.074)
Born $<$ 1956	1.177**	1.176**	1.181**
	(0.077)	(0.077)	(0.076)
Observations	40,805	40,805	40,805
Note: Hazard ratios, SE on parentheses	*p<0.1; **p<0.05; ***p<0.01		

Following the hypotheses presented earlier, we decided to run separate analyses for women with traditional and egalitarian gender values (see Section 1.4 for details on this indicator). The models in Table 1.4 show that while for women with more traditional gender values, the effect of both employment status and employment instability are positive, for women with more egalitarian perspectives, the effects go from neutral to negative. Although they point in the right direction, these results are less robust than those reported for males, given the smaller number of cases resulting from the split in this sample and the intrinsically more complex dynamics between employment instability and fertility among women.

Table 1.4: Cox Proportional Hazard Model Estimates, First Child — Females

	Dependent variable:	
	First Birth Timing	
	Traditional	Egalitarian
Employed (ref.)		
Unemployed (*tv*)	1.632**	0.758
	(0.233)	(0.187)
Low Instability (ref.)		
High Instability (*tv*)	1.281	1.060
	(0.161)	(0.103)
Age Ends Education $\leqslant 17$ (ref.)		
Age Ends Education > 18	0.777***	0.653***
	(0.097)	(0.056)
Born 1976 - 1986 (ref.)		
Born 1956 - 1976	1.121	1.167**
	(0.160)	(0.073)
Born $<$ 1956	1.292	1.189**
	(0.160)	(0.082)
Had Partner (*tv*)	8.377***	9.562***
	(0.139)	(0.111)
Observations	12,417	33,726
Note:	*p<0.1; **p<0.05; ***p<0.01	

1.5.2 Effects of Employment Instability on Completed Fertility

Figure 1.10 and Figure 1.11 present the predicted probabilities of having at least 1, at least 2, at least 3 and at least 4 children for men and women aged 45 or more with a specific set of values on our control variables (for the full regression results see the appendix).

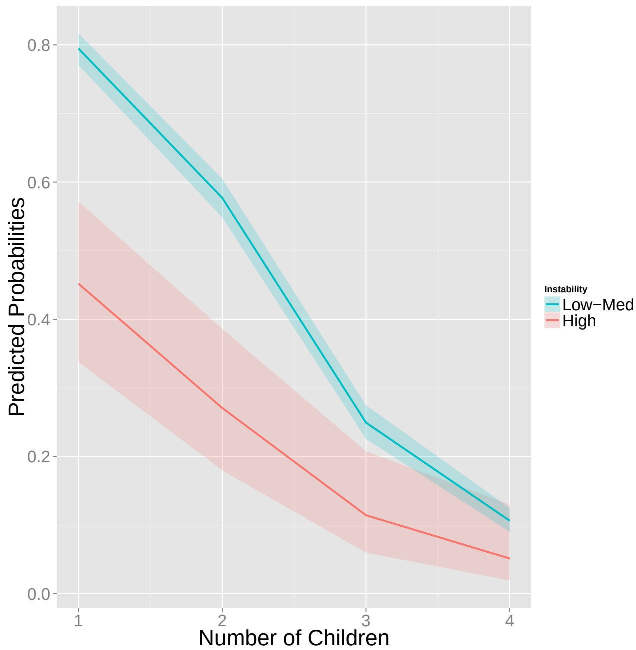


Figure 1.10: Predicted Probabilities and Confidence Intervals from Logistic Regression Models, Number of Children - Males, Age $\geqslant 45$, Nationality=European, Age End Education <18.

The results for men with lower education are in line with those found in our previous analyses: In all cases the probabilities are higher for those with more stable sequences, and the differences are particularly strong for the first two outcomes – having at least one and/or at least two children. In other words, the probability of remaining childless is higher for those with more unstable trajectories as well as the probability of having only one child. Although differences are less marked, the probabilities of having at least three and four children are higher for those with more stable trajectories, although in the last case, the effect is not statistically significant.

In the case of women this time we decided not to split the analyses

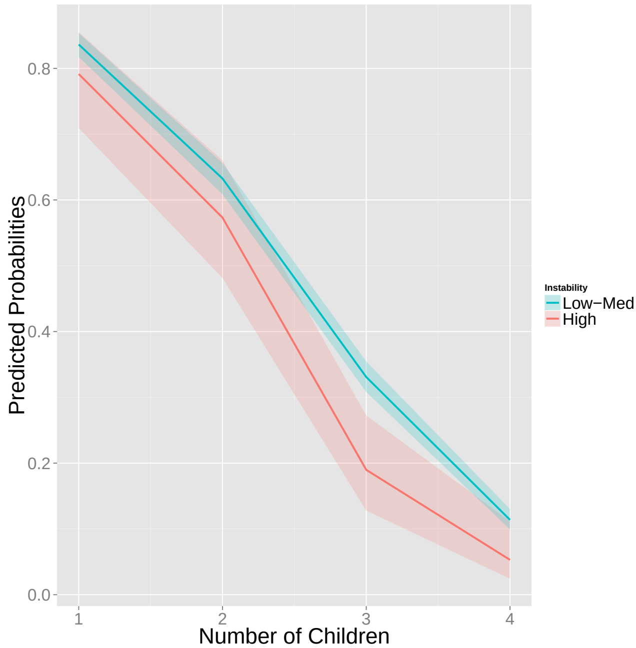


Figure 1.11: Predicted Probabilities and Confidence Intervals from Logistic Regression Models, Number of Children- Females, Age $\geqslant 45$, Nationality=European, Age End Education <18

according to gender values given the smaller size of the original sample (only women above age 45). In contrast to what we observed for males, the most visible differences are at higher order parities, although the differences are smaller. Nevertheless, in all four models, the probabilities are higher for those with more stable careers. Although the exclusion of part-time episodes as a source of uncertainty among women might also be introducing some bias in our analyses, our results including and excluding part-time spells from our instability measure remained extremely close to each other (omitted).

1.6 Discussion

In relation to the substantive conclusions, we showed how unemployment and part-time job episodes in individuals' biographies have increased over time, resulting in more complex and unstable trajectories for both men and women. We interpret this, at least partially, as the result of the process of flexibilization/deregulation of the French labor market, a process observed in most European countries over the last decades.

Our main objective was to assess the effects of this increased instability on the timing of first births and on the final number of children. According to our first hypothesis, we expected employment instability to be particularly disruptive in the case of men, affecting both the timing and the intensity of fertility. Our results confirmed this hypothesis, showing that for men, unstable trajectories lead both to postponement of first births and to a higher probability of remaining childless or to having fewer children than those with a more stable relationship with the labor market.

Although the direct effects proved to be relatively strong, an important part of the influence of employment instability is indirect, affecting the union formation process. Individuals with turbulent careers certainly experience difficulties making decisions about the right time to have children, but they might experience even stronger ones in finding a partner in the first place.

According to our second hypotheses, we expected employment instability to have less disruptive effects in the case of women with a preference for a traditional gendered division of labor. In general, our results for females were less robust and visible than those obtained for males and we believe there are both substantive and methodological reasons behind this.

In fact, it is likely that the combination of a strong norm against childlessness and strong family policies make this effect less pronounced in France that in other contexts, at least for lower order parities. On the methodological side, the more complex nature of the analysed relationship among women presents a series of challenges. The main one continues to be the identification of women with different roles with respect to the division of paid and unpaid work within the household, which is not an easy task since those roles might change over the life course and they might also be a function of an individual's previous history in the labor market. Nevertheless, even a correct classification will probably not fully solve the problems of reverse causality between the degree of attachment to the labor market and childbearing.

In spite of that and in spite of the fact that our attempts to identify different subpopulations of women were not perfect, the results obtained provided hints towards the confirmation of our hypothesis. We showed that employment instability has a positive influence on the timing of fertility for women with more traditional views about the division of labor and a negative influence among those with more egalitarian views.

With respect to completed fertility, we found visible effects on the probabilities of having relatively larger families, but not on the probabilities of having one or two children, which makes sense considering the characteristics of the institutional and cultural context in France regarding family formation.

In reference to the discussion introduced in section 1.2.1, our results confirmed the relevance of analyzing the *duration* and *persistence* of unemployment, hence, the advantages of trajectory over snapshot indicators. Our results also largely support the hypotheses put forth by Adsera (2004, 2011) or Schmitt (2012), regarding the negative effects of long-term unemployment on family formation transitions. As mentioned earlier, the opposite effect, as proposed by Kravdal (2002), was only found among women with more traditional views regarding the division of paid and unpaid work.

Finally, our results gain additional relevance if we consider that the cohorts included in the analysis of completed fertility have not fully experienced the effects of labor-market deregulation. Incoming labor-market cohorts should show increasingly unstable trajectories and stronger depressing effects on fertility levels, if the gap between insiders and outsiders continues to widen.

1.7 Appendix

Table 1.5: Logistic Regression Models- Final Parity Achieved | Males 45+

	At least 1 Child	At least 2 Children	At least 3 Children	At least 4 Children
Intercept	$1.35\ (0.07)^{***}$	$0.31\ (0.06)^{***}$	$-1.10\ (0.07)^{***}$	$-2.13\ (0.09)^{***}$
High Instability	$-1.55\ (0.25)^{***}$	$-1.30\ (0.27)^{***}$	$-0.95\ (0.36)^{**}$	$-0.79\ (0.52)$
Nationality - Other	$0.55\ (0.23)^{*}$	$0.83\ (0.19)^{***}$	$1.00\ (0.17)^{***}$	$1.08\ (0.20)^{***}$
Age Ends Edu >18	$-0.11\ (0.13)$	$0.15\ (0.11)$	$0.11\ (0.12)$	$-0.13\ (0.17)$
Deviance	2003.53	2601.60	2245.21	1362.68
Num. obs.	1795	1795	1795	1795

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\cdot}p < 0.1$

Table 1.6: Logistic Regression Models- Final Parity Achieved | Females 45+. Up to secondary Education

	At least 1 Child	At least 2 Children	At least 3 Children	At least 4 Children
Intercept	$1.63\ (0.07)^{***}$	$0.54\ (0.05)^{***}$	$-0.70\ (0.05)^{***}$	$-2.05\ (0.08)^{***}$
High Instability	$-0.30\ (0.23)$	$-0.25\ (0.19)$	$-0.75\ (0.24)^{**}$	$-0.83\ (0.42)^{*}$
Nationality - Other	$-0.02\ (0.22)$	$0.33\ (0.18)^{\cdot}$	$0.78\ (0.17)^{***}$	$1.02\ (0.20)^{***}$
Age Ends Edu >18	$-0.40\ (0.12)^{***}$	$-0.16\ (0.10)$	$-0.42\ (0.11)^{***}$	$-0.47\ (0.17)^{**}$
Deviance	2016.10	2824.18	2626.42	1453.13
Num. obs.	2307	2307	2307	2307

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$, $^{\cdot}p < 0.1$

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Chapter 2

FEEDBACK MECHANISMS IN THE POSTPONEMENT OF FERTILITY

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Abstract

In this chapter we describe the process of fertility postponement initiated in Spain in the mid-1970s using a dynamic model that considers the interaction of four main factors. *Rising economic uncertainty* and the *expansion of higher education* provide the original impulse which is later amplified by the feedback generated via *social interaction* as young men and women start imitating the behavior of their peers and friends. As the pressure to conform to an early family formation standard is reduced, the postponement process gains momentum. This multiplier effect explains a substantial part of the observed trend, but its pace and extent also depend on the resistance exerted by *social norms*. Our model tries to capture the dynamic mechanism by which norms shape behaviors and behaviors shape norms,

in a process of mutual dependence. This feedback loop between individual actions and aggregated outcomes allows us to bridge the micro and macro levels of analysis and it proves to be a key element in the explanation of the massive and ongoing transformation of fertility patterns in Spain in the last decades.

2.1 Introduction

The idea that reproductive preferences (intentions) represent a key element of fertility change was already present in classic demographic transition theory. Notestein (1953) recognized that the set of social norms, values, and beliefs sustaining a particular economic and demographic regime are "deeply woven into the social fabric and are slow to change." For decades, demographers have attributed the lag in the decline in fertility during the demographic transition to people's resistance to adapting to a new survival scenario.

Some of the most prominent contemporary fertility theories argue that normative shifts, either in the form of secularization (Lesthaeghe and Van de Kaa, 1986) or changing gender values (McDonald, 2000; Esping-Andersen and Billari, 2015), are the main engine of change in fertility levels. However, most of the time norms seem to be resisting rather than promoting demographic change.

Norms have prevented not only more rapid fertility declines during the demographic transition, but also expected increases in the mean age at childbirth in eastern European countries (Perelli-Harris, 2005; Mynarska, 2010), the adoption of modern contraceptive methods (Munshi and Myaux, 2006), and the spread of alternative family formation behaviors among Japanese men and women (Rindfuss et al., 2004).

But norms are too complex for most conventional modeling techniques and most of the time they remain at the theoretical level. In this chapter we explicitly model the dynamic relationship between norms and behavior and we argue that the evolution of (age) norms can also explain a substantial part of the postponement of fertility in Spain.

The explanation we propose has four central elements: the expansion of tertiary education, the increase in economic uncertainty, the role of social interaction as a multiplier of these structural changes, and the dynamic relationship between intentions and behavior. Our objective is to go beyond the assessment of the relative contributions of each of these elements, and to analyze the mechanisms at the individual level that explain the emergence of an aggregate trend.

We structure the chapter as follows. First, we discuss some of the approaches used to analyze the dynamics that have pushed fertility to later ages, and their limitations. Next, we describe the model target and the model itself, and present the empirical data used to calibrate it to the Spanish case. Finally, we present several simulated scenarios designed to help us gain insight into the mechanisms at play in the rise in the mean age at first birth (MAFB).

2.2 The Dynamics of Fertility Postponement

2.2.1 Social Interaction

Social interaction became a mainstream concept in demography after the results of the Princeton Project highlighted the geographic and linguistic boundaries surrounding the onset and the pace of fertility decline. Thereafter, the spread of information and attitudes through social networks was a key element of most models of fertility change during the demographic transition.

According to Casterline (2001), the initial attempts to incorporate into fertility theories the notion of diffusion were based on an eminently practical goal: namely, the acceleration of the spread of contraceptive techniques in developing countries. This might explain why birth control has been the main focus of most of the empirical applications of diffusion models (Entwisle et al., 1996; Kohler, 1997; Kohler et al., 2001; Montgomery and Casterline, 1993; Munshi and Myaux, 2006; Rosero-Bixby and Casterline, 1993).

The most recent wave of studies on social interaction and fertility have relied on the availability of detailed datasets and new methods to empirically analyze the role of social networks in family formation decisions (Aparicio Diaz et al., 2011; Balbo and Mills, 2011; Balbo and Barban, 2014; Lyngstad and Prskawetz, 2010; Mathews and Sear, 2013). These studies focused less on fertility *change* and more on the question of how family and friends influence fertility attitudes and behaviors in the transition to parenthood. They defined the mechanisms through which interaction affects behavior: i.e. *social learning*, a self-initiated process through which agents obtain information and knowledge from others; or *social influence*, a process through which other people and their behaviors exert pressure and control over the individual.

From a dynamic perspective, social interaction also operates through different mechanisms. Of those proposed by Kohler et al. (2002), two are particularly relevant in our analysis: *social feedback mechanisms* and *status quo enforcement*.

Social feedback is the process through which social interaction increases the pace or the extent of the original change in fertility behavior triggered by socioeconomic changes. In this case, imitation or the intensification/relaxation of social pressure generates an effect that can become independent of the initial change in material conditions.

Status quo enforcement refers to the mechanism, described above, through which social norms generate resistance to innovative behavior. So far, there have been few empirical analyses of this process (for an example, see Munshi and Myaux (2006)). But as we will try to show in the remainder of this article, status quo enforcement might be one of the fundamental dimensions of fertility change.

2.2.2 Feedback Loops Between Preferences and Behavior

The decision to have a child has been analyzed using multiple behavioral frameworks, like the "ready, willing, and able" approach developed by Coale (1973), or the rational action theory embedded in most economic models. Recently, attempts have been made to promote and incorporate the theory of planned behavior (TPB) (Ajzen, 1985) into the analysis of reproductive decision-making (Morgan et al., 2011).

Demographers became interested in the TPB primarily because of the role intentions play as close predictors of observed behavior within the TPB framework. In fact, the main focus of empirical studies on intentions has been to test their capacity to predict future fertility trends (for a review, see Morgan (2001)).

However, the TPB framework has been criticized for its static nature, as the theory does not adequately take into account the recursive loop between intentions and behavior (Sniehotta et al., 2014; Morgan and Bachrach, 2011). The focus of the TPB on the synchronic perspective blurs the process through which intentions themselves change as a result of previous behaviors.

The discussion surrounding the TPB evokes the longstanding sociological debate between those who see agency (behavior) as the key mechanism in the explanation of social processes, and those who highlight the role of structures (norms, institutions). Also known as the "voluntarism vs. determinism" debate in other disciplines. Scholars who have attempted to overcome this dichotomy have generally focused on the recursive dynamics between agency and structure (Giddens, 1984; Bourdieu and Wacquant, 1992).

This perspective implies the existence of a mechanism through which new behaviors contribute to a change in the prevailing norms, which in turn feed back to the individual level, thereby shaping the intentions of subsequent generations in a micro-macro-level loop.

While they are harder to model, these mechanisms can illuminate more complex, and potentially more interesting dynamics like the "downward spiral of fertility" described by Goldstein et al. (2003) (who argued that the *apparent* decline in the ideal family size in Germany and Austria was a product of the experiences of cohorts living in low-fertility regimes), or the emergence of multiple equilibria regarding the timing of fertility described by Kohler et al. (2002). In the latter, feedback generated through social interaction explains rapid and substantial changes in the MAFB.

2.2.3 Equilibrium Between Intentions and Behavior?

Even if we imagine that intentions and behavior are mutually dependent, the question of what this relationship looks like remains. Previous postponement models have assumed that intentions and behavior converge, at least in the long run.

In the model by Aparicio Diaz et al. (2011), the decision to have a child at time t results in a new aggregated probability (intention) at $t+1$. Here the effect of previous behavior in the updating of people's preferences is linear and cumulative. Intentions and behavior remain perfectly aligned. The model by Kohler et al. (2002) allows for a temporary mismatch of intentions (the desired MAFB) and behavior (the observed MAFB), although in the long run they also converge to an equilibrium. However, the available empirical evidence on intentions suggests that this assumption might be misleading.

Regarding the quantum of fertility, Bongaarts (2001) argued that in pre-transitional societies the ideal family size tends to be below the observed total fertility rate (TFR), but that this relationship shifts in post-transitional settings. He concluded that "a declining desired family size is indeed one of the principal forces driving fertility transitions, but in reality levels of fertility often deviate substantially from stated preferences."

Unfortunately, the amount of available data on preferences regarding the timing of the transition to parenthood is very limited, and comparisons of the evolution of the ideal relative to the observed mean ages are difficult to make. However, data from 2006 showed that people's preferences and behavior were far from being in equilibrium (Testa, 2006). For example, women surveyed in Spain stated that the ideal age for becoming a mother was around 25.5, while the observed mean age at first birth for that year was 29.3.

The scarce evidence available suggests then that the evolution of the *ideal mean age at first birth* relative to the *observed mean age* will follow a similar pattern to the one observed for the ideal family size relative to the TFR: i.e. above the ideal before a certain amount of control over fertility has been achieved, and below the ideal after the mean age at motherhood has been pushed beyond a certain threshold; as appears to have been the case in most European countries in the mid-2000s (Testa, 2006).

2.2.4 Educational Change

The positive association between education and the age of the transition to parenthood has long been recognized in demography (Marini, 1984; Rindfuss et al., 1980). Research on the topic has identified two distinct dimensions of the effect of education on fertility: enrollment and post-enrollment. The first effect refers to the difficulties which can arise in balancing the roles of student and mother, while the second is related to the higher opportunity costs of childbearing for highly educated women.

According to recent estimates of the contribution of increasing education to the postponement of fertility in three European countries (Britain, France, and Belgium), the joint effects of enrollment and post-enrollment are responsible for most of the rise in the mean age at first birth (Neels et al., 2014; Ní Bhrolcháin and Beaujouan, 2012). However, the findings of another set of studies suggest that education might not be the main driver of fertility postponement (Rendall et al., 2010; Rindfuss et al., 1996). The results presented later in this paper show that this conclusion depends on the way we measure the effect of education, as we will see, the *direct* effect of educational expansion (the effect coming from the change in the composition of the population by education level) explains only a modest fraction of the total delay in marriage/parenthood, although this in not the only way the effects of education are expressed on fertility decisions.

2.2.5 Unemployment

The relationship between economic constraints and fertility decisions has received substantial attention in recent years after a series of studies suggested that the longstanding negative correlation between prosperity and fertility levels had changed its sign (Adsera, 2004; Ahn and Mira, 2001; Kohler et al., 2002; Myrskylä et al., 2009). Although a vast body of literature on this topic has been generated, it is still difficult to obtain some stylized facts regarding the size and direction of the effect of unemployment on fertility decisions.

A series of studies have reported no significant effects (Kravdal, 2002; Kreyenfeld, 2010; Ozcan et al., 2010), while other studies have found strong negative effects that range from a 25% reduction in the risk of having a first birth in France (Pailhé and Solaz, 2012), to a 60% reduction in Germany (Kreyenfeld, 2005), and a 40% reduction in Spain (Baizán, 2006).

The considerable diversity of the institutional settings studied and the difficulties researchers face in distinguishing between income and substitution effects partially explain the ambiguity of some of the results found in the literature.[1] A potentially fruitful strategy for disentangling income from substitution effects is to distinguish women in traditional male breadwinner arrangements from women in dual-earner households. Unfortu-

[1] According to Becker (1981) an income rise will not only increase the demand for children, but also the indirect costs of forming a family; i.e. the potential income and career opportunities that parents have to give up in order to spend time with their children. An *income* effect is observed when the demand for children is positively affected by an increase in resources, and a *substitution* effect is observed when the effect is negative.

nately, the information needed to make this distinction is often missing from surveys, and only a few studies have provided results accounting for the employment status of both members of the couple. Most of these studies have confirmed the assumption that substitution effects prevail when women are (exclusively) caregivers, while unemployment tends to depress or delay fertility when both members of the household work (Baizán, 2006; Vignoli et al., 2012).

To account for the effect of unemployment in our model, we had to reconstruct the historical series of unemployment rates in Spain from the earliest available figures in the 1930s (Fig. 2.1). The shortest series corresponds to the unemployment rates computed from the information provided by the Spanish Labor Force Survey (EPA, *Estadística de Población Activa*), which is considered the most reliable source in Spain for labor market indicators, including unemployment rates. The second series shows the figures obtained from the official employment offices. Although it covers a longer period of time, this indicator only consider workers in the formal economy, which could lead to an underestimation of the unemployment rates. The other crucial difference between the two indicators is that the registered unemployment rate is computed over the working-age population (16–64), whereas the EPA rate considers only the economically active population, and thus provides higher estimates. However, our goal in presenting both series is not to highlight their differences, but to show that Spain seems to have enjoyed a period of very low unemployment until the 1970s, when the rate increased dramatically, coinciding with the increase in the MAFB, presented in Fig. 2.2.

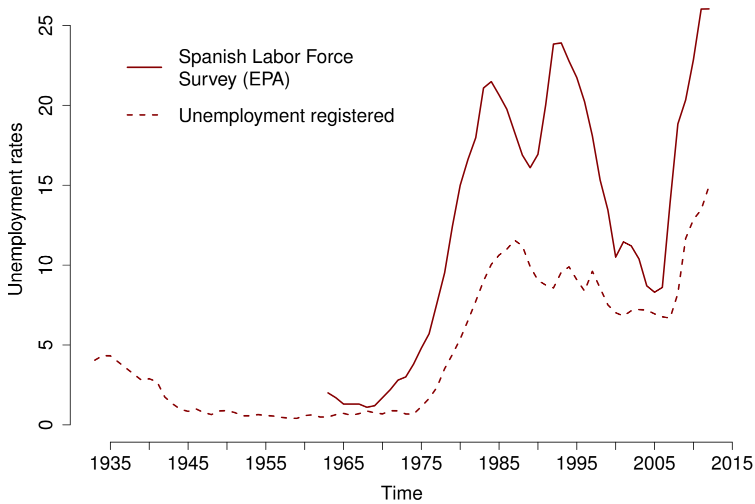

Figure 2.1: Unemployment rates, Spain 1933–2012: (1) Unemployment measured by the Spanish Labor Force Survey (EPA), and (2) Unemployment registered (Statistical Yearbooks of Spain). Source: Spanish Statistical Office (INE, 2015)

2.3 Model Target

The main targets of our model are the evolution of the mean age at first birth (MAFB) and the evolution of the schedule of age-specific fertility rates (ASFR), which for Spain are available only from 1975 onward.

Although most European countries registered significant postponements in the MAFB in the last decades of the twentieth century, in Spain the increase was particularly intense. As we can see in Fig. 2.2, the mean age increased by about five years over the observed period.

An initial exploration of the curve suggests the effect of unemployment in shaping the trend: a similarly steep increase until the mid-1990s, a deceleration up to the end of the first decade of the twenty-first century, and another peak coinciding with the most recent economic crisis.

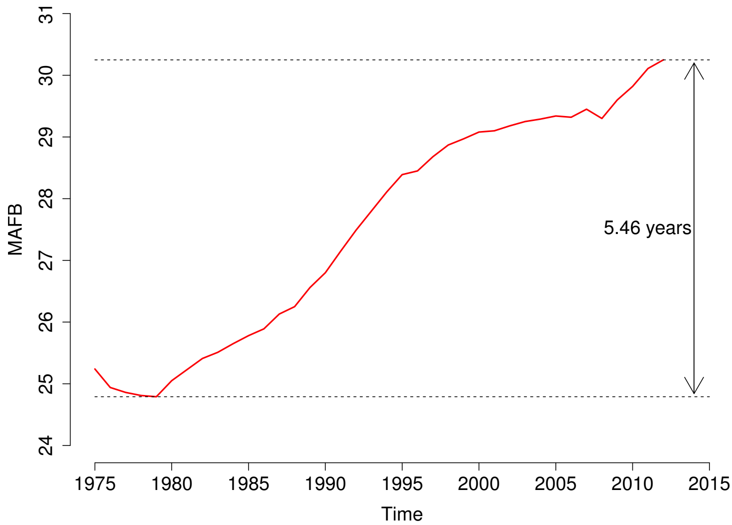

Figure 2.2: Mean age at first birth (MAFB), Spain 1975–2103. Source: Spanish Statistical Office (INE, 2015)

Figure 2.3 provides more information about the nature of this change. The evolution of the age-specific fertility rates shows that the increase in the mean age shown in Fig. 2.2 has been the result of a reduction in fertility rates at younger ages, but also of the increase in births at older ages. From 1975 to 2012 the peak of the distribution shifted from around age 23 to age 30. It is also interesting to note the small bump in the distribution from age 17 to age 24, which likely represents the contribution of migrant women, and which prevented an even greater increase in the mean age at the transition to motherhood by the end of the period.

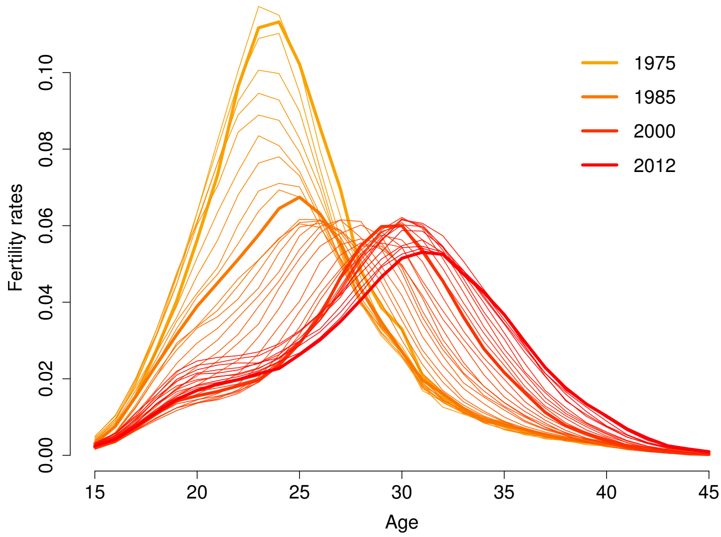

Figure 2.3: Age-specific fertility rates, First births, Spain 1975–2012. Source: Spanish Statistical Office (INE, 2015)

2.4 Model Layout

In our model, each woman older than age 15 has the intention to form a union or to have a child. These intentions are represented by transition probabilities which depend on individual characteristics (age and education) and on whether the agent has already found a partner or not.

The final probability with which an agent makes a decision to get into a union is the result of the agent's original intention (u), her employment status, and the influence coming from her network of friends (social influence). Analogously, the final probability of having a child inside the union is the result of the couple's original intention (f), their employment status, and the social influence of their network of friends. We assume, however, that having a child outside the union is not influenced by the same mediating factors, as most of these births will not be the result of a well thought-out decision; so even though we consider these events, they are not affected by unemployment or social influence. Each of these elements will be analyzed in greater detail in Sect. 2.5; here we provide a brief description of the central mechanisms.

The initial intentions u and f are obtained from empirical data, as described in Sect. 2.5.1. They capture both information on the behavior of previous cohorts and the agent's ideas regarding the maximum ideal age to marry/become a parent. The behavior of previous cohorts gives the agent (couple) an idea of what others can expect regarding her (their) family formation decisions given the age and education level. In this regard, u and f also capture one of the levels of social influence; the second one, a more local level, is captured through the agent's network. These expectations, however, are bounded by social (and biological) limits, which means norms determine to a certain extent how much and how fast intentions change.

Each year, before making a decision, agents consider not only their intentions but also their employment status and the behavior of their friends. An *unemployment multiplier* is introduced to captures the reduction in the probability of experiencing the transition to marriage (parenthood) when agents experience involuntary spells out of the labor market (Sect. 2.5.5).

Analogously, a *social influence multiplier* captures the influence from the closest network of friends and at the same time provides agents with information about how conservative/innovative the behavior of their friends is in comparison with the behaviors of previous generations. Social interaction positively reinforces those behaviors that are becoming increasingly acceptable/common in the population (Sect. 2.5.6).

The effect of educational expansion is introduced at the level of the education-specific intentions by changing the composition of the population by educational level as described in Sect. 2.5.4.

Figure 2.4 presents an example of a 25-year-old woman with tertiary education. Let's denote by $u(t, 25, 3)$—25 referring to the age and 3 to the educational level—her intention to get into a union in a given year t, which depends originally on how common or acceptable it is for a university-educated woman to marry (or cohabit) at age 25. The desirability/acceptability is given by the proportion of university-educated women of that age who got married in the previous year.

After considering her own employment situation and the behavior of her peers (social influence), our woman updates her original intention to marry and makes a decision based on her individual updated intention $u_i^*(t)$. The individual decisions of each of the 25-year-old and university-educated women in the population modify the norm regarding marriage at that age and educational level. The new information on how common or acceptable it is to enter a union for that population group is used in the next time step $t + 1$ to form the baseline intentions at age 25 of the following cohort of university-educated women—$u(t + 1, 25, 3)$—in a micro-macro loop.

When a woman decides to marry based on the prevailing norms, her background characteristics, her employment situation, and the influence from her network, the agent in the model that represented that woman now represents a couple, as depicted in Fig. 2.5. In the following year $t + 1$, the new couple—formed by a 26-year-old and university-educated woman and her partner—start with the intention to have a child $f(t + 1, 26, 3)$, which is shaped by the behavior of other couples the year before. In this

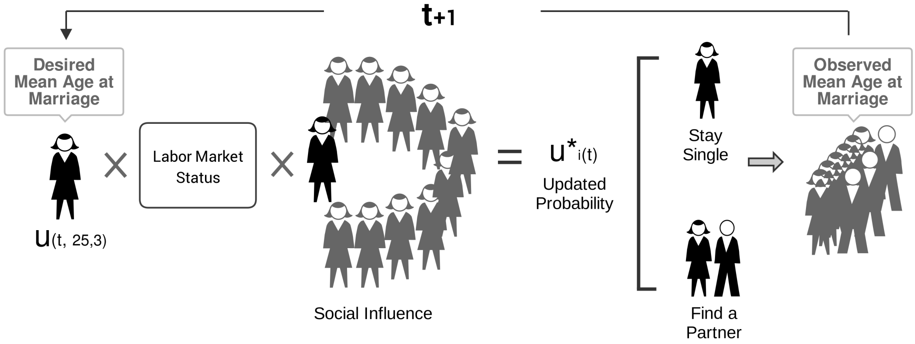

Figure 2.4: A model of fertility postponement: Union formation. The example of a 25-year-old and university-educated woman

case, the relevant background characteristics (age and education) are those of the woman, which are not necessarily the same as those of her partner.

As in the decision to marry, the couple update their original intention based on the influence of their network of friends, and after taking into consideration their joint situation in the labor market. The final updated intention to have a child will be $f_i^*(t+1)$. This process resembles that of the Bongaarts (2001) model, in which a series of intermediate factors prevent couples from realizing their fertility intentions.

The decisions of all couples in the population affect people's perceptions regarding the desirability/acceptability of such behavior. These perceptions in turn modify the fertility intentions of subsequent generations of couples, and, consequently, the desired mean age at first birth.

However, the interesting question here is how exactly people come to update their expectations and form their preferences by taking into account the experiences of previous cohorts. In other words, how norms adapt to people's behavior and how in turn they shape their future actions.

The existence of ideal ages as well as age *deadlines* for the transition

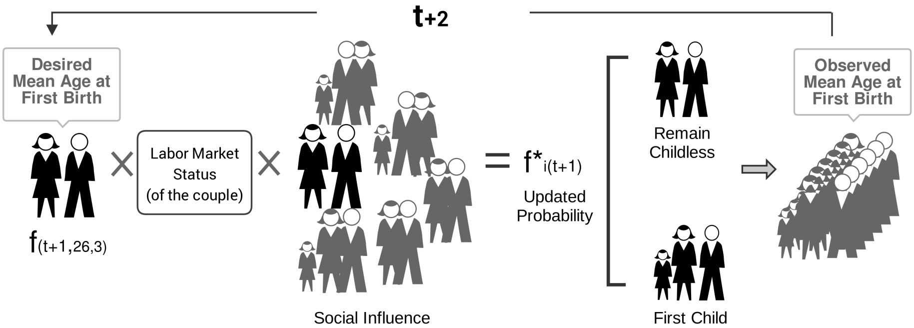

Figure 2.5: A model of fertility postponement: First birth. The example of a couple formed by a 26-year-old and university-educated woman and her partner

to parenthood has been well documented (Settersten and Hägestad, 1996; Billari et al., 2011; Van Bavel and Nitsche, 2013). It is likely that these markers, specially those related to the *proper* age for having a child, change during the postponement transition as a result of the mechanism described above. It is also likely, however, that the ideal age for having a child does not increase indefinitely. A certain threshold must exist after which people start resisting the push toward later childbearing ages.

Our assumption is that people will follow the behavior of previous cohorts and update their expectations as long as the threshold that marks the upper limit of the ideal age for having a first child had not been crossed. The threshold marks the point at which individuals will start resisting further increases of the MAFB even if the material incentives push in the opposite direction. We believe that this resistance is triggered by the proximity of the biological limit but also by a series of social norms, for which we model different thresholds according to the education level of agents.

In addition, we believe that the postponement of motherhood encounters some resistance at the beginning of the process due to a similar path dependence process generated by prevailing norms. It takes time for individuals to realize that conditions are changing and to start adapting their preferences accordingly. In Sect. 2.5.8 we provide details on how these dynamics are introduced in the model.

To summarize, we understand the process of postponement as the result of the interaction of the four main factors introduced above. Is in response to *rising economic uncertainty* and increased opportunity costs associated with the expansion of *higher education* that couples in Spain start postponing marriage and having children. The expansion of education and the increasing uncertainty in the labor market provide the original push to the MAFB. However, this original change is amplified and sustained via *social interaction* as young men and women start imitating the behavior of their peers and friends. People's beliefs about the ideal age for marriage and for becoming a mother (norms) play a crucial role both at the beginning and at the end of this process. Initially, norms generate resistance associated with the time it takes for individuals to realize that conditions and expectations are changing. Towards the end of the process, the resistance is generated by the proximity to the social and biological limits of reproduction.

Undoubtedly, the process we study here has been the result of a larger number of factors. The reasons we chose to put our focus on these particular four are varied: First, their theoretical relevance. Second, the fact that the four factors selected are able to closely reproduce the observed macro level trends we are targeting while keeping the model in a level of complexity that still fit the format of a research article. Finally, the model we present here does not intend to be the ultimate explanation of fertility postponement, but serves to illuminate a specific set of elements that had remained relatively unexplored in more traditional statistical approaches.

2.5 Technical Description

Our simulation runs for 70 years, from 1944 until 2014, and we base our simulations on Spanish data (more details about the data are provided in Sect. 2.6). The ages of the initial population are randomly assigned according to the female population structure of Spain from the 1940 census (INE, 2015). Starting the simulation in 1944 ensures that all of the women of reproductive ages (15+) will be out of their reproductive period when our analysis of the MAFB begins.

The model contains five procedures for agents which are carried out at each time step: aging, partnership formation, reproduction, entry into/exit from the labor market, and the building of a network. Each time step (or iteration) corresponds to one year. At each new iteration the agents age, and they may die off according to the corresponding age- and year-specific mortality rates of Spain (HMD, 2015).

As they enter the simulation, the agents are assigned the final educational level they will achieve: primary, secondary, or tertiary. At age 15, an individual becomes an adult who can find a partner (marriage or cohabitation), who might reproduce, and who builds her own social network by choosing a maximum of ν contacts from a larger pool of potential friends based on their social distance with respect to education. From age 16 agents can become unemployed according to observed age- and sex-specific probabilities. The agents do not remain in the simulation beyond age 45.

The population is composed of female and couple agents. In addition to the information of the female partner, couple agents have information on the male member, as shown in Table 2.1. Table 2.2 summarizes the global variables used in the simulation.

Table 2.1: Agents' characteristics

Agent variables	Variable name	Values
Identity number	*id*	1, 2, 3, ...
Age	*x*	0–45
Age partner	*xp*	15–53
Age at first birth	*xb*	15–45
Education level	*edu*	1: "primary" 2: "secondary" 3: "tertiary"
Marital status	*ms*	0: "single" 1: "married/cohabitation"
Employment status	*es*	0: "agent employed" 1: "agent unemployed"
Employment status partner	*esp*	0: "partner employed" 1: "partner unemployed"
Network	*net*	# individuals in the network

2.5.1 Transition Probabilities

As was mentioned above, the intentions on which our agents' behaviors are based are represented by empirical transition probabilities. To obtain these probabilities, we first estimate the original union and fertility rates using the multistate model presented in Fig. 2.6. The model resembles the classic illness-death model without recovery used in medical research (Beyersmann et al., 2011). All of the individuals start at stage 0-*Single*

Table 2.2: Global parameters

Global parameters	Parameter name	Value
Starting year	*iniYear*	1944
Final year	*finYear*	2014
Sex ratio at birth	*SRB*	0.515
Minimum age at birth	*minAge*	15
Maximum age at birth	*maxAge*	45
Recurrence in Unemployment	σ	0–0.99
Maximum network size	ν	1, 2, 3, ...
Fertility rate for parity 1+	$f2$	0–0.99

Without Children, and have the potential to stay in this state or to move to either state 1-*Union*, or to the absorbing state 2-*First Child*. After reaching state 1, individuals can either stay or leave the state to enter state 2. Each of these transitions is governed by a cause-specific hazard from which we obtain the Nelson-Aalen estimators of the cumulative hazard for each event.

From the estimators of the cumulative hazard, we derive the sets of age- and education-specific fertility probabilities for a first birth inside of a union $f^o(x, edu)$, fertility probabilities for a first birth outside of a union $fs^o(x, edu)$, and union probabilities $u^o(x, edu)$. These sets of probabilities represent both the observed and the intended fertility behaviors at the beginning of our period of interest, as, for the sake of simplicity, we assume that behaviors and intentions are in equilibrium at that time. For parity one or higher, the fertility rate is $f2$ for all individuals.[2]

[2] As we model the effect of labor market exits exogenously, we need a set of initial probabilities that is net of the effect of unemployment to avoid an overestimation of this effect. Unfortunately, as the dataset we use for the estimation of the original probabilities does not contain information on the employment histories of the interviewees, we have to provide a rough estimate of the effect of unemployment. As we noted in Sect. 2.2.5, Spain did not have high levels of unemployment until the mid-1980s, which means that the effect of unemployment on our cohorts born in 1940–1960 would have been relatively

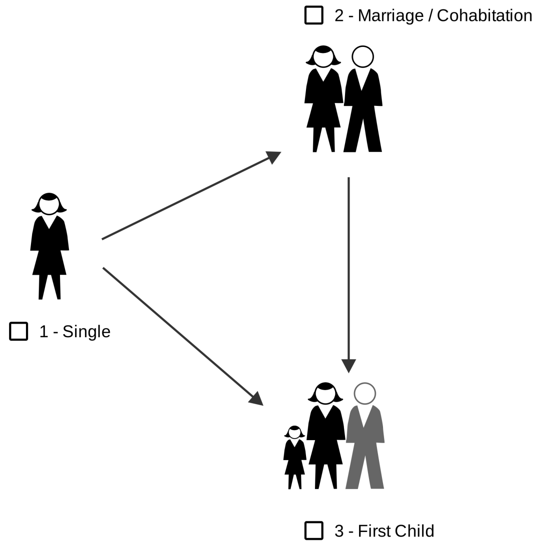

Figure 2.6: Multistate model: (1) Single, (2) Marriage/Cohabitation, and (3) First child

2.5.2 Initialization of the Model

These observed fertility and union rates correspond to the cohorts of females born between 1940 and 1960. We restrict our sample to this period for two reasons. First, we want to avoid mixing a large number of cohorts with different labor market and educational experiences. Second, the fertility schedules of these cohorts shaped the period mean ages at first birth in the mid-1970s, before the beginning of the increase we are trying to model (see shadowed area in Fig. 2.8).

For the computation of the MAFB, we need all of the agents to be exposed to the entire set of intensities presented in Fig. 2.7. Hence, starting the simulation in 1944 ensures that all of the women who entered the initial

mild. We assume a decreasing effect by age: compared with the original probabilities, the final probabilities are about 15% higher at age 15, only around 5% higher at age 30, and about the same by the end of the reproductive period at age 45; as shown in Fig. 2.7.

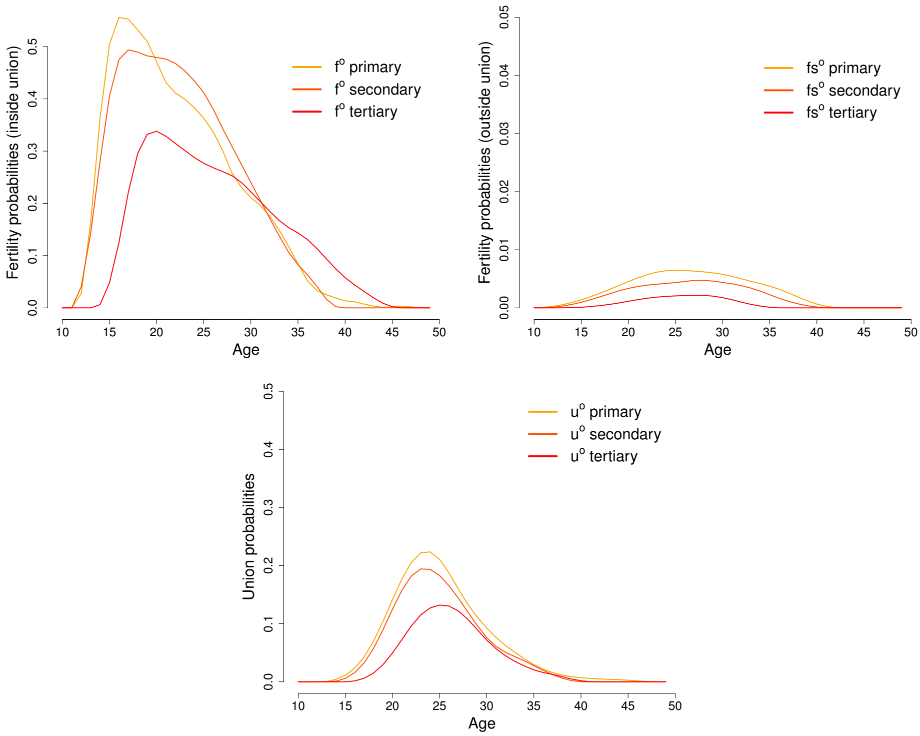

Figure 2.7: Age- and education-specific probabilities from multistate model. Cohorts 1940–1960, Spain. From left to right: (1) Fertility probabilities inside union, (2) Fertility probabilities outside union, and (3) Union probabilities. Note: A different vertical scale is used for fertility probabilities outside the union

population being older than 15 (solid black line in Fig. 2.8) and were not exposed to the entire set of probabilities from age 15 to 45 are not considered in the computation of the simulated MAFB in 1975. Moreover, this initialization procedure (1944–1974) prevents us from assigning an initial parity to the agents and an age at first birth to those with parity one or higher, for which we have no empirical reference.

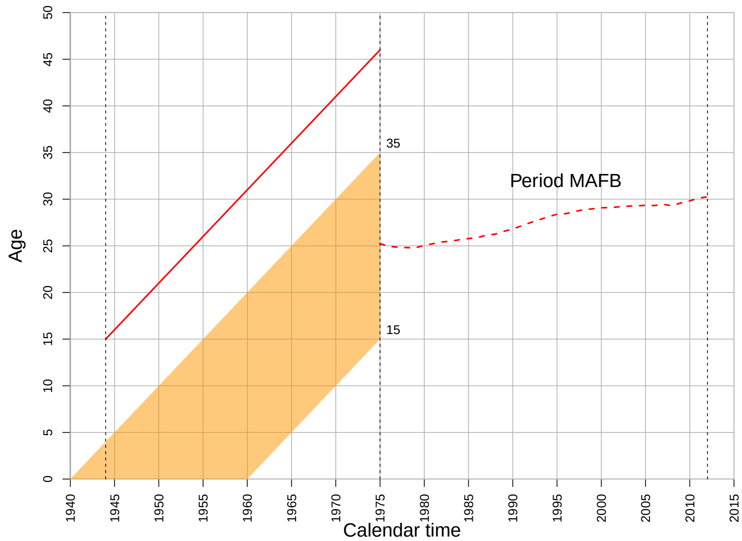

Figure 2.8: Lexis diagram of the female cohorts used in the initialization of the model

2.5.3 Age of Partners

When an agent enters a union, a random age and the corresponding age-specific unemployment rate are assigned to her partner. The age is obtained from a truncated normal distribution, using the age of the agent plus two years ($x_i + 2$) as the mean value, and $a = x_i - 4$ and $b = x_i + 8$ as the lower and upper limits of the age of the partner:

$$xp_i \sim N_{[a,b]}(x_i + 2, 1) \tag{2.1}$$

2.5.4 Evolution of Educational Attainment

Tertiary education has expanded rapidly among women in Spain: the share of women who completed tertiary education rose from 5% of those born in the late 1930s, to one-third of those born in the 1970s, to around 45% of the more recent cohorts (Castro-Martín and Martín-García, 2013).

As we can see in Fig. 2.9, since the late 1930s the proportion of female newborns who complete tertiary education has been increasing almost linearly. The 2011 census provides reliable figures for the generations born up to 1980; after that point, and based on the figures presented above, we assume a continuation of the linear increase in the proportion of women who access a tertiary level education, a linear declining trend in the share of women who only have secondary education, and a stagnation in the share of women who never leave the primary level of education (at under 10%).

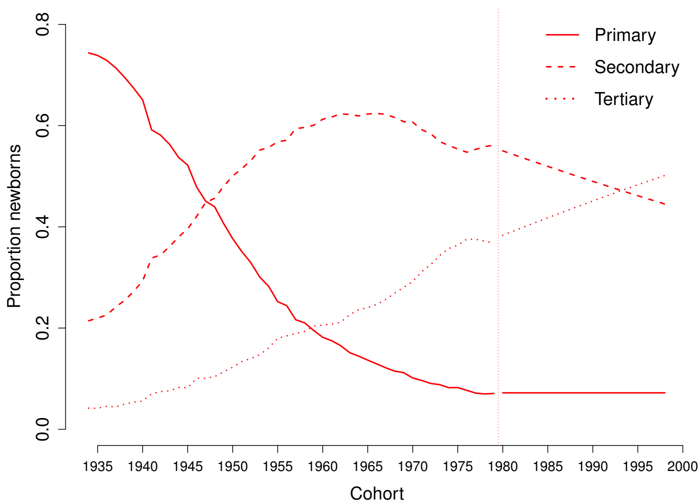

Figure 2.9: Observed and predicted proportion of newborns by achieved education level. Female cohorts, Spain 1934–1998. Source: 2011 Spanish Census, Spanish Statistical Office (INE, 2015)

In our model, education is defined according to the three levels mentioned above, which correspond to the number of years of formal schooling: fewer than six (*primary*), from six to 13 (*secondary*), and more than 13 (*tertiary*). Each year we assign the newborns in our model a level of education matching the proportions that each of these levels represent in the total female population, as shown in Fig. 2.9.

2.5.5 Unemployment Effects

Starting from the observed unemployment rates, we obtain the proportion of the population who were unemployed in each year of our simulation, by age group and sex. From these series we then model the exits from the labor market, while assuming that a proportion σ of those who were unemployed in the previous year will stay in that state.

We assume that unemployment affects an individual's decisions about whether and when to enter a union and to have a first child, both within and outside of a union. The strength of this effect depends on the employment status of the couple, with three different scenarios: (1) the agent is unemployed ($es_i = 1, esp_i = 0$); (2) her partner is unemployed ($es_1 = 0, esp_i = 1$); and (3) both members of the couple are outside of the labor market ($es_i = esp_i = 1$). In practice, that means that the original fertility and union rates of each agent i are modified by an unemployment multiplier um_i defined as

$$um_i(x_i; \alpha) = \frac{1}{1 + \exp(-0.1(x_i - \alpha))} \tag{2.2}$$

where x_i is the age of the agent, and α a parameter that depends on the employment status of the couple and determines the strength of the effect. Figure 2.10 shows the unemployment multiplier over the union rates $u(t, x, edu)$ for the different combinations of the employment status of both members of the couple. These sets of α values are the ones we used in our final model in Sect. 2.7.1, which provides a good fit for our target.

In the three cases the effect is more pronounced at younger ages. For instance, for those couples in which only the female partner is unemployed the probability of entering a cohabiting union or having a first child (after being in a union) is about 80% of the original probability if the female partner is 25 years old, about 65% if the male partner is unemployed, and about 30% if both partners are out of the labor market.

The function of the multiplier for the fertility probabilities is the same, although the effects are slightly smaller than the multiplier for the union probabilities. We assume that the margin to postpone the formation of a new household in response to economic uncertainty is larger than the margin to postpone the decision to have children given biological constraints.

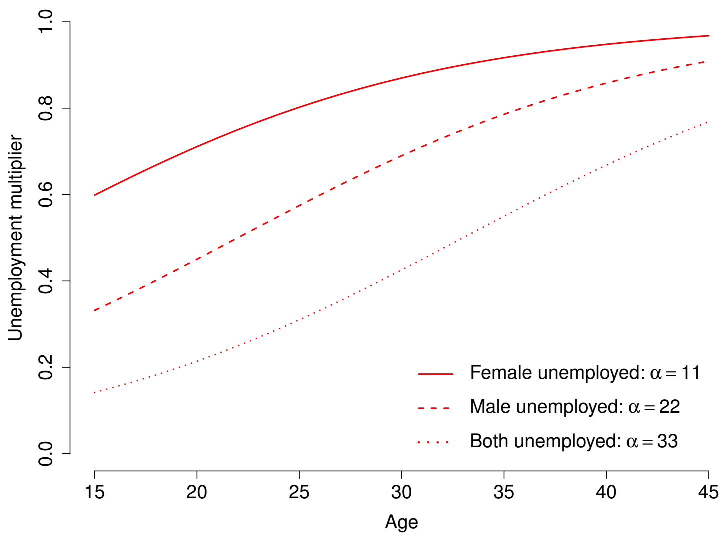

Figure 2.10: Effects of unemployment by age on the original fertility and union rates

2.5.6 Social Influence Effects

As mentioned before, agents do not base their decisions about the timing of marriage/cohabitation and the transition to parenthood exclusively on their immediate material conditions (unemployment) and their perceived opportunities (education); their choices are also influenced by their network of friends. As the decisions of the members of a given agent's network are themselves determined by the labor market conditions and their education, the strength and the direction of the influence the network exerts will be shaped by its members' material conditions and their perceived opportunities. In other words, a social feedback mechanism is triggered by a change in these conditions, which in turn reinforces and amplifies the original effect.

At age 15, each agent forms a network composed by a maximum of ν members of the same age. The agents randomly choose these contacts from a pool of potential friends based on a social distance function that depends on their educational level. The social distance between two agents i and k is defined as

$$sd_{ik} = \exp\bigl(-\beta(|edu_i - edu_k| + 1)^2\bigr) \tag{2.3}$$

where edu_i and edu_k are the respective educational levels, and β is a parameter that controls the level of educational homophily in the agent's network.

Equation 2.4 shows that the social influence si_i that an agent i of age x_i receives from her network is based on the distance between the proportion of members in her network who are already mothers ρ_i, and the average proportion of mothers of age $x = x_i$ in all networks in the previous generation (10 years before) ρ_x^*. This means that the degree of influence on the agent to have a child at any given age is based on how common/acceptable is to have a child at that age relative to how common/acceptable it was to have a child at that age 10 years ago. The reference to the past allows agents to know not only which behavior is accepted/expected but also how behavior is *changing*, and to follow innovative behavior as long as her (their) friends are adopting it.

$$si_i(x_i;\gamma,\kappa) = \begin{cases} \dfrac{1}{1+\exp\left(-\kappa_1(x_i - \frac{\gamma_1}{1+\rho_i-\rho_x^*})\right)} + 1, & \text{if } \rho_i - \rho_x^* > 0.05 \\ 1, & \text{if } |\rho_i - \rho_x^*| \leq 0.05 \\ \dfrac{1}{1+\exp(-\kappa_2(x_i - \frac{\gamma_2}{1+\rho_i-\rho_x^*}))}, & \text{if } \rho_i - \rho_x^* < -0.05 \end{cases} \tag{2.4}$$

where $\gamma = (\gamma_1, \gamma_2)$ and $\kappa = (\kappa_1, \kappa_2)$.

For the transition to marriage/cohabitation, the social influence function works in a similar way, although instead of considering the proportion of mothers in the network we use the proportion of members of the network who were already married/cohabiting π_i, and the average proportion of agents of age $x = x_i$ who were already married/cohabiting in all networks in the previous generation π_x^*. In both cases the strength of the effect is given by parameters $\gamma = (\gamma_1, \gamma_2)$ and $\kappa = (\kappa_1, \kappa_2)$.

When the difference between ρ_x^* and ρ_i or π_x^* and π_i exceeds the 5% threshold, the social influence multiplier si_i either augments ($\rho_x^* < \rho_i$, $\pi_x^* < \pi_i$) or reduces ($\rho_x^* > \rho_i$, $\pi_x^* > \pi_i$) the original rates $u(t, x, edu)$ and

$f(t, x, edu)$. If the absolute difference is less than 5%, the social influence has no effect. Figure 2.11 illustrates the effect for a set of γ and κ values that offer a good model fit (see Sect. 2.7.1).

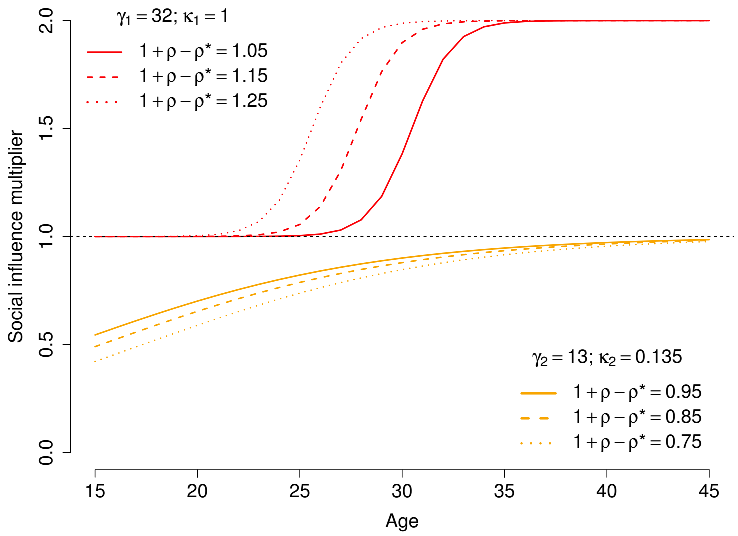

Figure 2.11: Social influence by age

We assume that the agents' decisions become progressively independent of the behavior of their friends as they approach the upper limit of the family formation period, and that other influences become stronger. Hence, we model a decreasing negative effect of social interaction as age increases. Conversely, we assume that the positive effect will increase with age as it joins other influences (proximity to the biological limit, family influences) in pushing forward the transition to parenthood.

The parametrization of these effects is not an easy task given the lack of previous empirical references. The values we present here were obtained after several exercises with the calibration of the model. For example, given these parameters the probability of marriage/childbearing for an agent who is 30 years old is about 90% of the original probabilities if there is one fewer marriage/mother in her network (assuming the networks have an average size of 20) than in the average of all networks of agents of that age 10 years before ($si_i = 0.9$). By contrast, if there is one additional marriage/mother in her network, her probability of marriage/childbearing increases by about 40% ($si_i = 1.4$).

2.5.7 Model Equations

Following the explanations introduced in Sect. 2.4, the unemployment and the social influence effects are captured by the individual multipliers um_i and si_i to obtain for each agent i the individual updated probabilities (intentions) of union formation $u_i^*(t)$ and of having the first child within marriage $f_i^*(t)$:

$$u_i^*(t) = u(t, x_i, edu_i) \times um_i(x_i; \alpha) \times si_i(x_i; \gamma, \kappa) \tag{2.5}$$

and

$$f_i^*(t) = f(t, x_i, edu_i) \times um_i(x_i; \alpha) \times si_i(x_i; \gamma, \kappa) \tag{2.6}$$

As was mentioned above, the fertility probabilities of women who have children outside of marriage or cohabitation are not affected by unemployment and the local social influence, as given the cultural framework in Spain we assume that this type of event is frequently unplanned, and is therefore less conditioned by labor market or peer behavior considerations.

2.5.8 Micro-Macro Loop

The effects of unemployment and social influence at the micro level result in a series of decisions about marriage and childbearing which modify the ideal ages of these events at the macro level, and hence the intentions at the micro level of subsequent cohorts. This process starts in 1975, once the initialization process (1944–1974) is complete. At $t = 1975$, $u(t, x, edu) = u^o(x, edu)$, $f(t, x, edu) = f^o(x, edu)$, and $fs(t, x, edu) = fs^o(x, edu)$, where u^o, f^o, and fs^o are the probability transitions obtained from the multistate model discussed in Sect. 2.5.1 and Fig. 2.7.

Equation 2.7 describes how this process of reciprocal dependence works.

$$u(t+1, x, edu) = \begin{cases} \dfrac{\overline{u^*}(t, x, edu)}{\max\left(\frac{\overline{u^*}(t,x,edu)}{\overline{u}(t,x,edu)}, \theta\right)}, & \text{if } \frac{\overline{u^*}(t,x,edu)}{\overline{u}(t,x,edu)} < 1 \\ \\ \overline{u^*}(t, x, edu), & \text{otherwise} \end{cases} \tag{2.7}$$

where $u(t+1, x, edu)$ represents the baseline intentions at time $t+1$ by age and educational level. $\overline{u^*}(t, x, edu)$ is an *average* by age and educational level of the updated probabilities defined in (2.5), and $\overline{u}(t, x, edu)$ is an *average* by age and educational level of the original probabilities (without effects) at time t. $\overline{u^*}(t, x, edu)$ recovers the effects of unemployment and social influence on the original intentions of the previous year. An analogous mechanism applies for the computation of the transition probabilities to parenthood inside unions $f(t + 1, x, edu)$.

The parameter that governs the loop between intentions and behavior is θ, which depends on the observed MAFB and the educational level, as shown in Fig. 2.12. It controls the position of the threshold after which agents are no longer willing to postpone family formation. When θ is closer to one then all of the effects of unemployment and social influence are recovered in the new baseline, and the desired and the observed mean ages grow at a similar speed. As intentions near the ceiling imposed by people's preferences, then θ approaches zero, and the new baseline does not consider a portion or all of last year's effects; people thus resist further increases in the ages at marriage and childbirth. A similar resistance is observed at the beginning of the postponement process as information about the transformation of the age at family formation reaches everybody in the population.

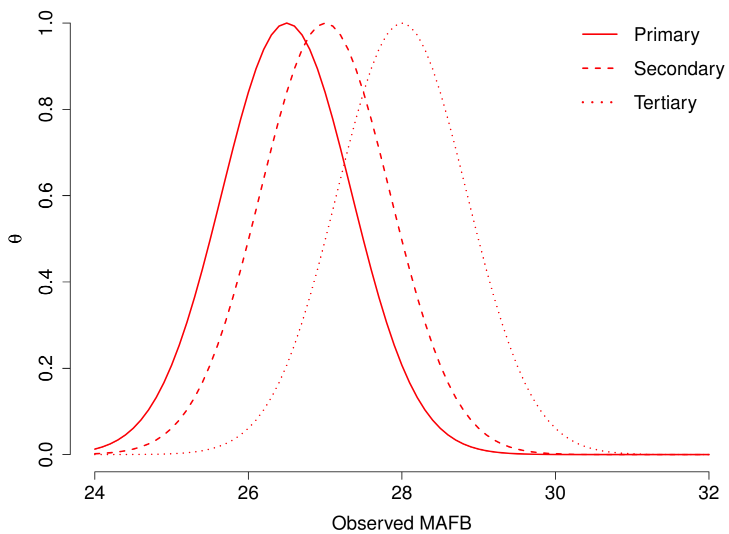

Figure 2.12: Desired mean age thresholds by education level

In Sect. 2.7.2 we show different scenarios resulting from a series of assumptions about the dynamics between the observed and the desired timing of family transitions.

2.6 Data and Tools

Our model could be described as a semi-artificial population model, a particular type of agent-based model (ABM) which, according to Bijak et al. (2013), results from the introduction of ABM techniques into a predominantly empirical discipline like demography. Semi-artificial population models are is characterized by the combination of empirical and simulated data.

For the computation of the original union and fertility rates, we use the 1991 Sociodemographic Survey (INE, 2015). It provides a large representative sample of the Spanish population (age>10), with 159.154 observations.

To obtain the initial age structure of the population we use the 1940 census. For the initial distribution of the population by education, we use information from the 1970 census, which is the first to present disaggregated population figures. Both censuses are from the Spanish Statistical Office (INE, 2015).

The age- and sex-specific mortality rates from 1944 to 2014 were obtained from the Human Mortality Database (HMD, 2015).

For the reconstruction of the long unemployment series, we made use of various sources. The numbers of people who were registered as unemployed came from the Statistical Yearbooks of Spain published by the Spanish Statistical Office (INE, 2015). We also used an interpolation of the censuses from 1930 to 2011 to obtain the number of working-age individuals. The Spanish Labor Force Survey (EPA) series 1960–1978 came from Carreras and Tafunell (2006). Finally, the series for the period 1979–2014 came from the Spanish Statistical Office (INE, 2015).

Simulations were run in R (R Core Team, 2015) and NetLogo (Wilensky, 1999), using the `RNetLogo` extension (Thiele et al., 2012). To obtain the estimates from the multistate model we used the `survival` (Therneau, 2015) and the `mvna` (Allignol et al., 2008) R packages. The code is optimized to take advantage of parallel computing using the `snowfall` R package (Knaus, 2013).

2.7 Results

We begin this section by presenting the fit to our model's target, as described above. In a second step, we present scenarios for different assumptions of some of the key mechanisms. Finally, we try to assess the individual role of each of the components of the model by presenting simulation results in which we alternately omit each of these effects.

All these simulations were carried out with the following values of the global parameters described in Table 2.2: Recurrence in unemployment $\sigma = 70\%$, maximum network size $\nu = 20$, and fertility rate for parity 1+ $f2 = 0.15$.

2.7.1 Original Model

Figure 2.13 shows the observed and the simulated MAFB. This fit corresponds to the non-linear specification of the model presented in Eqs. 2.5 and 2.6. Non-linearity here refers to the fact that the results the model provide cannot be predicted by adding up each of its individual components.

The parameters for the unemployment and social influence multiplier correspond to the values shown in Figs. 2.10 and 2.11. This specification closely reproduces the observed trend.

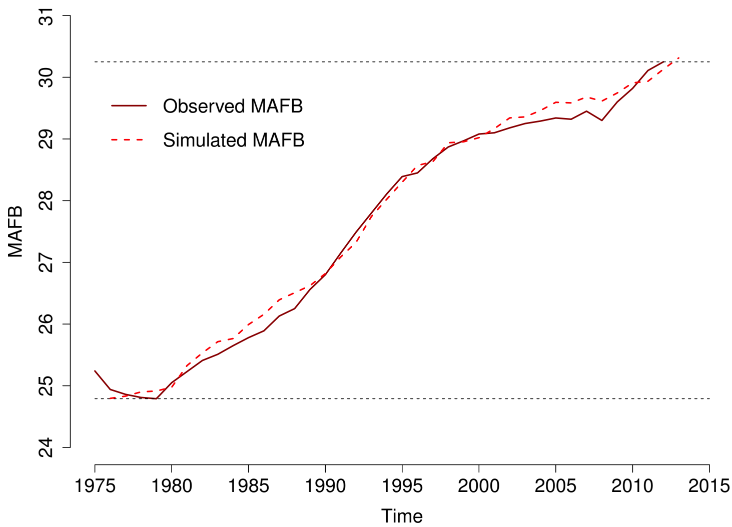

Figure 2.13: Observed vs simulated MAFB Spain, 1975–2013

Although the previous figure gives us an idea of how well the model approximates the data, the real challenge lies in matching the evolution of the distribution of ASFRs. As shown in Fig. 2.14, the model also reproduces this trend relatively well, especially the resulting distribution and the shift in the peak from around age 23 to around age 30.

2.7.2 Alternative Models

As described in Sect. 2.5.8, the bridge between the individual and the aggregate level in our model is provided by the influence that age norms regarding marriage and childbearing exert on the agents. Hence, the pace and the shape of fertility change will depend greatly on how these social norms shift in response to changes in behavior.

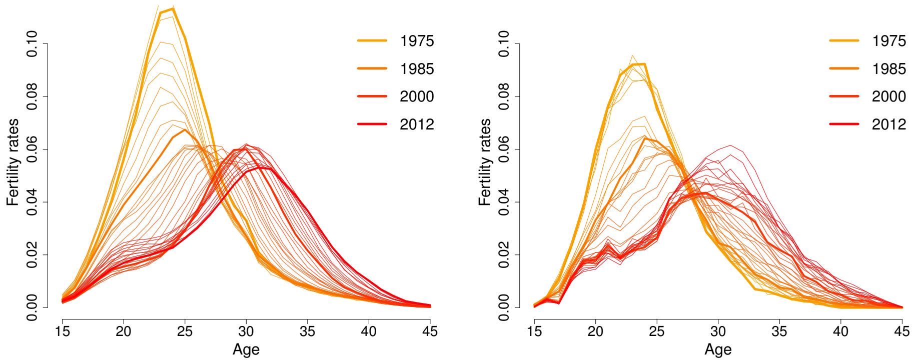

Figure 2.14: Observed (left) vs simulated (right) ASFR over time. Spain 1975–2012

In our original model, we assume that people's preferences are initially resistant to change. As mentioned before, this resistance is attributable to both the inertia of cultural norms and the time it takes for information regarding new material incentives to reach and be processed by individual agents. After the change in socioeconomic incentives picks up speed and individuals adapt their expectations, the age norms start to catch up with behaviors, but only until they reach the threshold created by people's beliefs about the upper limit of the ideal age range for marrying or having children.

In this section we compare our original model with two other linear specifications in which we remove the thresholds and the effect of norms is constant over time.

Figure 2.15 shows two different scenarios. In the left graph, age norms evolve at the same speed as behaviors. Each year individuals adjust their expectations by taking into account all of the information generated in the previous year regarding the material incentives and obstacles to marrying and reproducing, as well as the behavior of their peers ($\theta = 1$). In this case norms offer no resistance. On the other hand, the right graph presents a scenario in which norms are highly resistant to change, and individual preferences defy the most immediate changes in the socioeconomic incentives for marriage and childbearing ($\theta = 0$).

These scenarios result in significant overestimation and underestimation, respectively, of the postponement process. It seems reasonable to assume that during the postponement process age norms adapt in relation to changes in material conditions; but it also seems clear that this adaptation does not simply mirror the changes at the structural level.

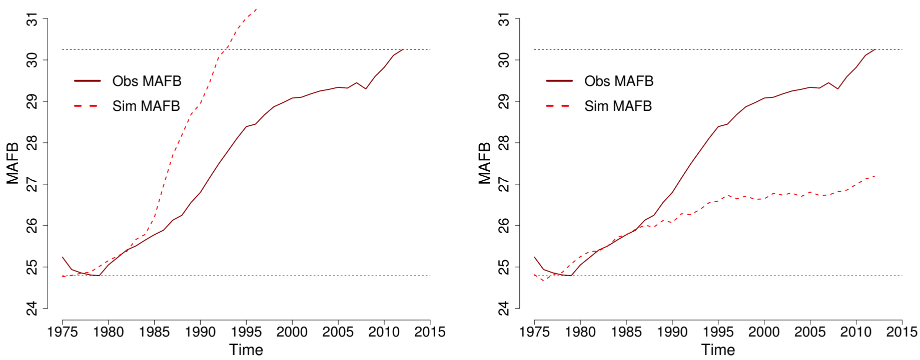

Figure 2.15: Observed vs simulated MAFB, Results from linear models. Spain, 1975–2012. Norms = Behavior (left) and Norms $<$ Behavior (right)

2.7.3 Net Effects

In this section we present the results of a series of exercises in which we try to isolate the different effects considered in our model. Figure 2.16 shows the results of a specification of the model in which we only consider the mechanic effect of educational expansion, as expressed in (2.8). The only driver in this case is the compositional change of the population by education level.

$$u_i^*(t) = u(t, x_i, edu_i) \text{ and } f_i^*(t) = f(t, x_i, edu_i) \tag{2.8}$$

Figure 2.17 presents a scenario in which the effect of unemployment is omitted (2.9), and one in which the effects of social influence are omitted (2.10).

$$u_i^*(t) = u(t, x_i, edu_i) \times si_i(x_i; \gamma, \kappa) \text{ and } f_i^*(t) = f(t, x_i, edu_i) \times si_i(x_i; \gamma, \kappa) \tag{2.9}$$

$$u_i^*(t) = u(t, x_i, edu_i) \times um_i(x_i; \alpha) \text{ and } f_i^*(t) = f(t, x_i, edu_i) \times um_i(x_i; \alpha) \tag{2.10}$$

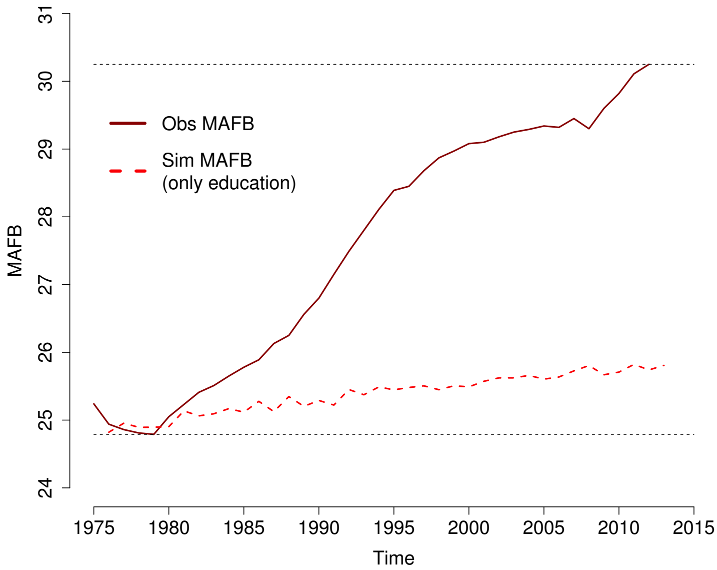

Figure 2.16: Observed vs simulated MAFB. Results from non-linear models with omitted effects. Spain, 1975–2012. Model with education only

The mechanic effect of education (the one that results exclusively from the compositional change in the population by education level) is substantially lower than we had originally expected, accounting for less than a fifth of the total increase in the MAFB by the end of the period. Although this modest effect of education questions the consensus regarding the causes of postponement, the result is not unexpected if we look at the relatively narrow gap between educational levels in the original distributions of age-specific fertility probabilities we use in the model (see Section 2.5.1). However, it is important to keep in mind that the result does not refer to the total effect that education exerts over the MAFB but to its most direct mechanism.

Regarding the multiplier effect of social influence (left panel of Fig. 2.17), the first element worth noting is its large contribution to the process, even though in this case its amplifying effect refers only to the delays caused by educational expansion. It's also interesting to note that in a world without unemployment the trend does not show the more recent increase which is likely associated with the latest Spanish economic crisis which resulted in a steep increase of unemployment rates.

The second model, which only accounts for the compositional change with respect to education plus the effect of unemployment (right panel of Fig. 2.17), results in a relatively small increase in the MAFB. This difference is attributable in part to the fact that while unemployment exclusively affects the proportion of people unemployed in that year (20% to 25% in years of high unemployment), the effect of social influence spreads through the networks, reaching most, if not all agents in the population.

The other interesting element is that the difference between the two is amplified by the fact that the model with social influence reaches the threshold, while the model without social influence stays below it. This helps to illustrate the relative futility of trying to isolate effects, and supports our assumption that the pace of the process cannot be explained solely by the measure of the strength of each of its individual components.

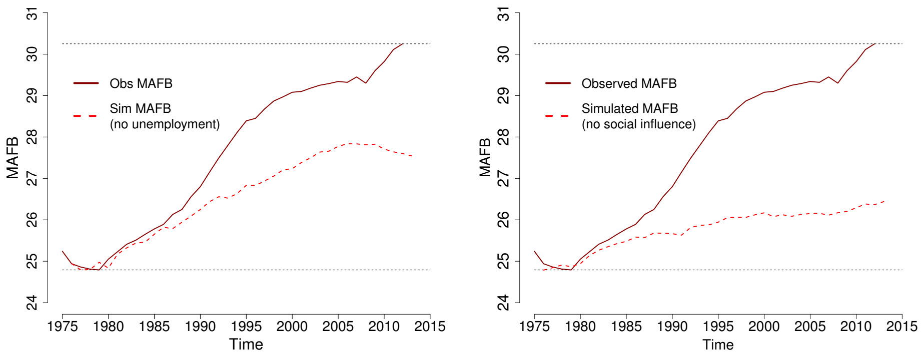

Figure 2.17: Observed vs simulated MAFB. Results from non-linear models with omitted effects. Spain, 1975–2012. Model without unemployment effect (left) and model without social influence effect (right)

2.8 Conclusions

Using an agent-based model we showed how the postponement of fertility in Spain can be explained by a set of relatively simple mechanisms at the individual level: rising opportunity costs of childbearing associated with higher education, growing economic uncertainty from an increasingly unstable labor market, and the multiplier effect of social interaction.

While the direct effect (compositional change) associated to educational expansion was substantially lower than we expected, our results showed that the feedback effects (multiplier) from social interaction were far more relevant than we had originally imagined. The extent to which networks amplify and spread an original force was particularly apparent when we compared the influence of social interaction with other factors that affect only a subset of the population, like unemployment. The empirical evidence we present here provides support for the claim that the echo generated by social interaction can exceed the impact of the original effects that triggered it.

Nevertheless, the existence of non-linear dynamics makes it impossible to describe the postponement process as a simple aggregation of each of its individual components, or to assess precisely the contributions of each of these components. But by using an ABM we were able to go beyond the assessment of the presence/absence of effects and explore the question of exactly how some of these mechanisms push forward the decision to form a family.

We found, for example, that for the shift of the peak of the distribution of age-specific fertility rates the increase in the *positive* influence on marrying/having children at later ages is as important as the increase in the *negative* influence at younger ages.

The other key element in the explanation of the postponement process is the micro-macro feedback loop through which past behaviors trigger normative changes, and which in turn translate into updated expectations for succeeding cohorts of men and women.

We tested different hypotheses and confirmed that the assumption of an equilibrium between preferences and behaviors leads to simulation results which deviate substantially from the observed trends. The key dynamic here seems to be the existence of a threshold after which people are reluctant to accept further delays in the age at which they start having children. Thus, it appears that norms are not so much *converging* or *lagging behind* as they are encouraging *resistance* to structural changes.

Understanding how age norms change is therefore essential to understanding the pace and the extent of fertility change. The formation of people's expectations and preferences is shaped by a larger set of elements than those we explored here. But while we did not directly address all of these factors, we do not intend to treat norms as black boxes. The strength with which people resist further increases in the timing of family formation depends on their expectations regarding the conditions for childbearing. In addition to their perceptions of the present and future dynamics of the labor market or the educational system, these conditions include elements such as the availability of affordable childcare or the existence of support systems that facilitate work-family balance.

On the methodological side, we tried to provide another illustration of how computational models present a great opportunity to add complexity and dynamism to our representations of human behavior.

In this article we have provided only a very general description of the postponement process, leaving many potentially interesting dynamics to be explored in future work. For example, researchers may want to investigate the influence of the size, the composition, and the level of homophily of the social networks; or the changes in the effects of economic uncertainty as the number of dual-earner households increases. Moreover, modeling the changing role of women with regard to paid and unpaid work would undoubtedly shed more light on our conclusions.

The classic schema of the innovators versus the followers of demographic change could also be tested by modeling different thresholds and ceilings (resistance and limits of normative change) for different subgroups of the population.

Finally, as we consider future scenarios, we believe that some of the forces that have been pushing the timing of family formation will continue moving in the same direction, at least in the medium term. There is room for further educational expansion in Spain, and a high degree of economic uncertainty is likely to be a feature of people's lives in the near future. These trends may be met with some resistance, but, as we noted above, there is no guarantee that behaviors will naturally converge with preferences. Thus, a large gap between behaviors and preferences could become a permanent feature in the coming years. The action taken to reduce this gap—or the failure to take action—will certainly shape the ongoing development of the timing of family formation in Spain.

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Chapter 3

MODELLING THE DECLINE AND RECUPERATION OF PERIOD FERTILITY FROM THE BOTTOM-UP

Abstract

The emerging consensus in fertility research places gender dynamics at the center of the explanation of fertility decline and its recuperation. This conclusion is largely based on cross-country comparisons of aggregate outcomes, but the micro-level evidence remains scarce and inconclusive. An alternative narrative has been proposed recently in which the recuperation of period fertility is a direct result of the end of postponement and not a consequence of a move towards greater gender equity. From this perspective, a focus on cohort trends reveals a more simple story of fertility decline and stabilization. This discussion allows us to test some hypothesis regarding the mechanisms behind long term fertility trends. We use an Agent-Based Model to capture plausible micro-level dynamics. In our model agents pursue the realization of their ideal family size against a series of constraints which directly affect their short-term intention to have

a/an additional child. We calibrate it using Spanish data but its main components are meant to apply to most European countries. We find that the U-shape pattern in period fertility is explained by factors other than gender dynamics within the household. Nevertheless, gender equity is still key to understanding recent fertility levels, more symmetrical preferences regarding work/family balance within the couple can explain the difference between achieving close to replacement fertility or remaining in the low fertility zone.

3.1 Introduction

For the most part of the 20th century fertility research in industrialized countries was almost exclusively preoccupied with understanding the determinants of fertility decline. Trends in the opposite direction were usually characterized as sudden, unexpected and temporary events outside the general framework of the transition theory (baby-booms). This changed when the recuperation pattern of period fertility became clear in the last decades of the past century and researchers started looking for theories that could explain both the sustained decline and subsequent recovery of Total Fertility Rates (TFR).

At least three types of such theories can be identified in the demographic literature. The first type argues that advances in social and economic development show a curvilinear relationship with period fertility, exerting a downward pressure up to a certain threshold after which the relationship turns positive (Myrskylä et al., 2009; Luci-Greulich and Thévenon, 2014).

Another stream of literature places developments in gender equity as the main driver of the U-shape trend of period fertility (Esping-Andersen and Billari, 2015; Goldscheider et al., 2015). More specifically, these researchers point to the initial conflict generated at the couple level by changing gender roles and its progressive reduction as institutions and households become more egalitarian. What they call the "first half of the gender revolution", when women's roles start to change as a consequence of their entry into the labor market, is associated with a trend towards "less family", which is reverted as men's roles adapt and the second half of the revolution is completed.

The third of these accounts is more strictly demographic, it highlights the role of postponement and its deceleration. According to this perspective, the increase in period fertility is largely a result of diminishing tempo distortions as shown by the relative stability of cohort indicators (Goldstein et al., 2009; Bongaarts and Sobotka, 2012).

In this paper we use and Agent-Based computational Model (ABM) to test some of the hypothesis derived from these conflicting narratives regarding long term fertility trends. First, we describe the model in detail and in relation to previous models, then we calibrate it using Spanish data and later we generate different scenarios to explore the relative role played by different factors in the evolution of period fertility since the second half of the 20th century.

3.2 Theories of Fertility Decline and Recuperation

The move towards higher levels of gender equity has become one of the key explanatory factors of period fertility trends in industrialized countries since McDonald (2000) suggested that the very low levels of period fertility during the 80's and 90's in a series of advanced economies were, in part, the result of an asymmetrical pace of development towards greater gender equity in individual-level institutions vs family-oriented institutions. This argument was originally confined to the difference between recovering replacement (or near-replacement) period fertility or remaining in a low period fertility scenario. More recent accounts, however, see gender dynamics as the fundamental driver of both period fertility decline in the second half of the 20th century and its recuperation in recent years (Esping-Andersen and Billari, 2015; Goldscheider et al., 2015; Anderson and Kohler, 2015).

Although some of the mechanisms identified by its proponents are different, the underlying narrative is essentially the same: The steep period fertility decline post-baby boom has been primarily driven by the movement towards greater gender equity, which resulted in a period of "uncertainty and normative confusion" (Goldscheider et al., 2015), a clash of old-conservative and new-progressive norms (Anderson and Kohler, 2015) or a "unstable equilibrium" (Esping-Andersen and Billari, 2015). In this accounts, the frustration of people's preferences resulted in a period of "less family", however temporary, followed by a recuperation of fertility as the second half of the gender revolution advances in some countries.

This argument is largely based on the apparent reversal of the negative correlation between period fertility rates and a series of indicators at the macro level, such as female labor force participation (Rindfuss and Brewster, 1996), Human Development Index (Myrskylä et al., 2009) or GDP per-capita (Luci-Greulich and Thévenon, 2014). The evidence at the individual level, however, is still inconclusive. Reversals have been reported mostly with respect to the dynamics of union formation and dissolution and have been obtained using mostly Scandinavian data (see Goldscheider et al. (2015) for a review).

However, focusing on a different set of indicators and on alternative pieces of evidence, a competing narrative emerges. According to this narrative the U-shaped pattern of change which has stimulated the reversals narrative is essentially a result of tempo distortions affecting the TFR. In fact, a look at completed fertility of cohorts born between 1950 and 1979 exhibits rather linear dynamics: a subtle increase in English speaking countries, stabilization in Northern Europe and a sustained decline in Southern European countries (Myrskylä et al., 2013). With respect to the apparent recuperation of fertility in the last one-to-two decades Bongaarts and Sobotka (2012) have shown how increases of the TFR are mostly driven by a slowing down of the postponement of the mean age at birth.

Rindfuss et al. (2016) have highlighted the formation of two clearly separated regimes, with a group of countries descending to and remaining in the low fertility zone, while the other group exhibits less problematic–close to replacement levels. Instead of a single bullet type of explanation, Rindfuss et al. (2016) point to the complex array of institutions in each country to explain their membership to one of these two groups.

The question is then whether the evolution of the TFR is indicating significant changes in the decisions of individuals regarding family size, and if that is the case whether those changes can be associated with changing gender roles and preferences.

3.3 The Agent-Based Approach and the Behavioral Foundation of Fertility Models

Fertility models tend to be separated between behavioral and formal. Formal referring to the analysis of necessary (true by definition) relationships between aggregate population quantities and behavioral referring to contingent relationship arising from the analysis of individual's decision making processes (Burch, 2003). Models of the "formal" kind have received most of the attention in fertility research, specially those dealing with cohort-period translation issues. The relatively marginal position of behavioral models is likely the result of the primacy of data over theory within the discipline.

In a recent article Goldstein and Cassidy (2016) review four well-known fertility models, three of which they classify as formal (dealing with period-cohort translation issues) and one as behavioral, although earlier they recognize that “implicit in each model is its own story of the behavior driving fertility”. Here the distinction formal/behavioral seems to be based only on the degree to which the interpretation of the model makes explicit reference to the experience of individuals.

The distinction between formal and behavioral goes far back in time. Advocates of the cohort approach, for instance, have seen the stronger behavioral foundation as one of its main advantages. Ryder’s answer to the question of why one should bother with cohort computations puts it in a simple but precise way: *it is the way people live*. [1].

Nevertheless, the problem of representing how individuals experience fertility might not lie in the adoption of a period or cohort approach but in the way our measures/models are built. Discussing the problem of reification in Demography, and in fertility in particular, Wilson and Oeppen (2003) show with a series of examples how the behavioral assumptions behind demographic measures are rarely made explicit. Reification refers to the process by which we naturalize abstract and arbitrary measures, resulting in a direct identification of the measure with the process that is

[1]Ryder’s original phrase is in the past tense, as he is referring to an exchange during the examination of his dissertation. The passage appears in a 1981 Citation Classic Commentary *http://garfield.library.upenn.edu/classics1981/A1981MS53800001.pdf*

supposed to represent, as when we refer to "Fertility" instead of the TFR. Their analysis leads the authors to an interesting observation: "Perhaps we might make more progress in our attempts to understand and explain trends in fertility if we examine the phenomenon in ways which come closer to the ways in which the issues present themselves to the "actors", whose individual behavior generates the aggregate indices of demographic study?".

Ronald Lee's "moving-target" model (1980) helps illustrate the discrepancies that might arise from an ex-post interpretation of aggregate quantities. Lee's formulation adopts a cohort perspective in an attempt to improve Ryder's "fixed-target" approach to the formation of family size preferences. Hence, he defines a desired completed family size D, which couples formulate at marriage but that is allowed to change over the course of their lives. The progression towards D, a quantity with a straightforward interpretation at the micro level, is defined by a typical schedule of age-specific fertility rates, which has no direct meaning from an individual's point of view. The interpretation problems arise when he tries to reconcile these two quantities.

Describing how changes in D affect period fertility, Lee explains that when D is rising couples might find themselves "behind schedule" having attained a smaller proportion of D at each-age than if D would had always been at its current level. While this "cumulative deficiency" makes sense from the modeler point of view, couples usually don't think what fraction of a baby they have lost *at each-age* when deciding to have another child.

Another stretch in interpretation is Lee's use of the concept of "no-longer-wanted" births: Children that become "unwanted" as individuals revise downward their desired family size. Evidently, this is hardly the way in which the vast majority of individuals in the real world think about their offspring.

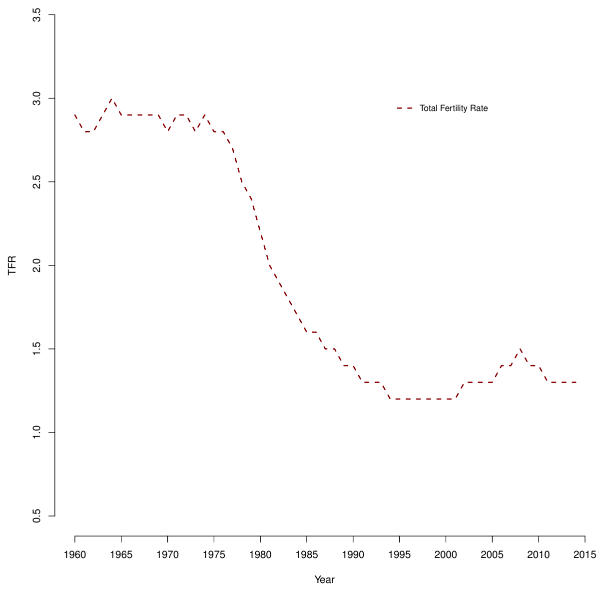
The point here is not to undermine the validity of the moving-target model, Lee's model is extremely useful (and one of the most direct influences of the model we present here). We rather want to emphasize the difficulty in translating aggregate quantities into plausible individual decision-making mechanisms.

In the following sections we will try to show how modelling at the agent level can help close this gap between models and reality, not only by providing a more fluid representation of individual behavior but also by allowing the systematic treatment of difficult-to-observe factors and dynamics.

3.4 Model Target: Fertility Decline and Recuperation

Our model's main target is the evolution of period fertility (TFR) since the second half of the 20th century. Although with slight differences in timing, during this period most industrialized countries in Europe and North America witnessed a significant decline of their TFR in a period of ten to twenty years followed by a stabilization and a modest to significant period recovery in recent years. Figure 3.1 presents the evolution of the TFR in Spain from 1960 to 2014. Around 1975 the TFR collapses, experiencing twenty years of sustained decline until it stabilizes around the mid 1990s. From the beginning of the 2000s period fertility experiences a small recovery until it falls again in the context of the last great economic recession.

Figure 3.1: Total Fertility Rates — 1960-2014 Spain.

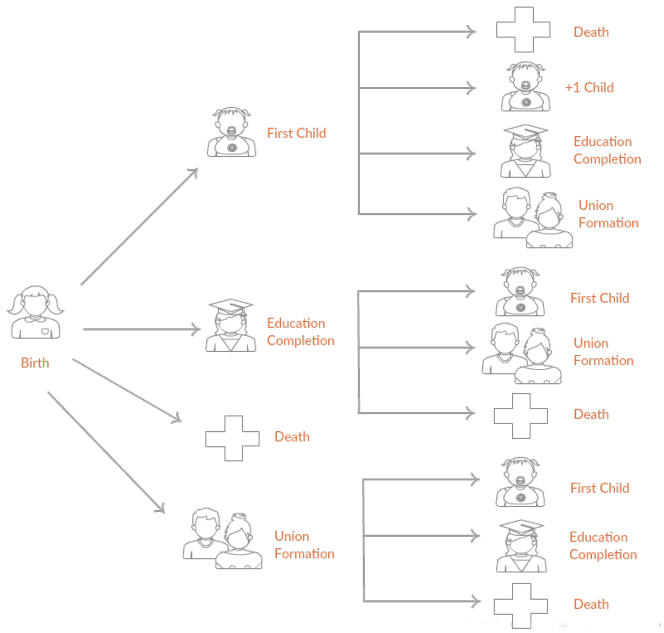


3.5 Model Description

Our model generates synthetic life histories from a combination of parametric and semi-parametric methods (described later in this section). Using these methods we sample individual waiting times to different life-course events from theoretical or empirical distributions. In the current specification, the length of these waiting times depends exclusively on the origin state and not in the duration spent in that state, thus the synthetic life histories produced by the model can be described as realizations of a continuous-time Markov process. A process that is structured around the transitions between four events: Leaving the education system, forming a union, having a/an additional child and dying. Figure 3.2 presents the state space and the set of potential transitions in our model.

Our simulated individuals are allowed to followed multiple paths, al-

Figure 3.2: States and Possible Transitions.



though some of these paths are more likely to be observed. The collection of all agents forms a synthetic population composed of males and females, although the focus is placed on the latter. Female agents live from birth up to age 50 and they can have up to 6 children. We make no distinction between cohabitation and marriage and we do not consider union dissolution. Although we are aware of the fact that the dynamics of union dissolution and repartnering affect fertility decisions, the complexity involved in modelling such dynamics exceeds the scope of this chapter.

Table 3.1 summarizes the characteristics of female agents.

3.5.1 Time

It is possible to distinguish three different dimensions of time in our model: Process time t relates to events, represents the duration, measures the time

Table 3.1: Agents' Caracteristics

Agent Variables	Variable Name	Values
Age	x	0–50
Age partner	*tp*	14–53
Education level	*edu*	1: "primary" 2: "secondary" 3: "tertiary"
Marital status	*ms*	0: "single" 1: "union"
Work-family preference	${}_fP$	3: "male Breadwinner" 6: "adaptive" 9: "dual Earner"
Work-family preference of partner	${}_mP$	3: "male Breadwinner" 6: "adaptive" 9: "dual Earner"
Ideal Number of children	D	0-7 children
Waiting Time to Comp. of Edu.	${}_ET$	0–30 years (seconds)
Waiting Time to Union Formation	${}_UT$	0 to ∞ (seconds)
Waiting Time to jth birth	${}_BT$	0 to ∞ (seconds)
Waiting Time to Death	${}_DT$	0 to ∞ (seconds)

spent in each state and the time left to the following event. Age x relates to individuals, as mentioned earlier it ranges between 0 and 50 years. Finally, calendar time c relates to the world beyond the model, it represents the dimension of time which allows for a connection with observed processes. Calendar time in our simulation experiment runs from the beginning of 1925 until the end of 2014 [2].

Figure 3.3 summarizes how time operates in our model. It depicts a hypothetical life trajectory of an agent that is born during the simulation, starts a relationship with cohabitation at age 25, has a child at age 29 and

[2] Although our target window goes from 1960 to the present, the initialization period from 1925 to 1960 allows for those agents that had already entered their reproductive ages (were 15 years old or more) by 1925, to be out of the simulation and avoid distortions coming from the incomplete information of these trajectories.

dies at age 50. The calendar time axis shows the years in which this progression takes place, the translation between these two axes is straightforward.

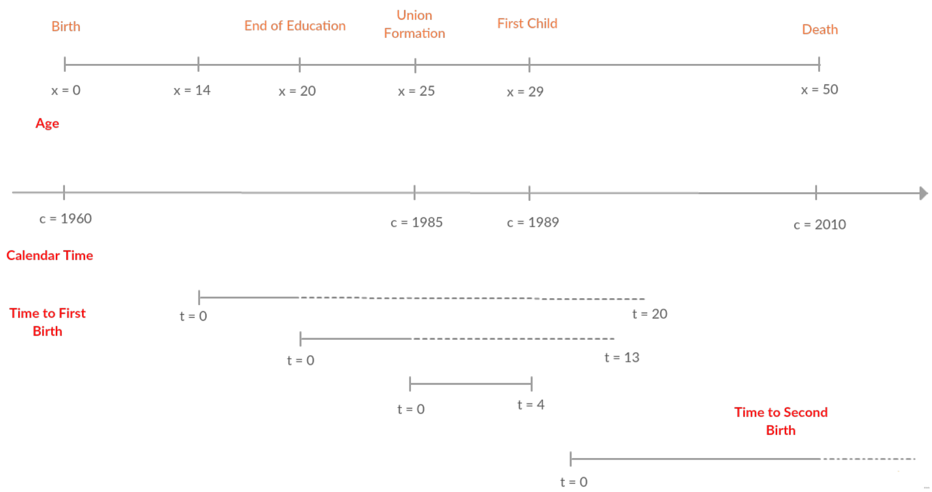
As we explain later in more detail, the waiting time to union formation ${}_{U}T$, the waiting time to the completion of education ${}_{E}T$ and the waiting time to death ${}_{D}T$ are assigned at birth and remain unchanged until those events occur or until the agent dies before experiencing other scheduled events.

The time to the j^{th} birth ${}_{B_j}T$ is assigned at age 14 when the agent develops the intention to have a child. In section 3.5.2 we describe in detail how this intention works and which are the factors that can affect it, for now it suffices to say that the stronger the intention the shorter the waiting time. We assume that most agents prefer to complete important life course transitions, like finishing their education and finding a partner, prior to transitioning into parenthood. Before experiencing these events most agents in our model have a relatively weak intention to have a child at some point in the future. But each time they achieve a relevant marker in the transition to adulthood their intention tends to become stronger.

In our example of figure 3.3, the agent develops an initial intention and corresponding waiting time at age 14. This original waiting time is updated after the agent revises her intention once she has finished her education. A new waiting time is produced, however this new waiting time also fails to be completed. After forming a union the agent updates her intention again and finally at age 29 she has her first child. She dies in 2010 at age 50 before having a second child.

The key point here is that when agents revise their *intentions* (I) after each life course event, they also update their *preferences* regarding family size (D) based on the prevalent ideals at the time of their transitions, creating a feedback between the micro and macro levels (we explain this in more detail detail in section 3.5.2). The distinction between preferences (or desires) and intentions is important here. Although the preferences regarding family size D are affected by the existing social norms they still remain defined in a more abstract level than intentions, which, in our model, are a more immediate predictor of future behavior as we explain in more detail below.

Figure 3.3: Time Dimensions



As in other discreet event simulations time advances with the realization of each event. At each iteration the algorithm realizes the event with the shortest waiting time from a list of all possible events for the entire population of agents. After the realization of each event the system is updated incorporating the new information and the simulation continues to the next run. By the end of a calendar year a series of aggregate indicators are computed from the life histories generated up to that moment, which are later used to asses the model fit.

3.5.2 Ideal Number of Children

According to Bongaarts (2001) the trend in desired family size is “the most critical determinant of future fertility”. The same role that Lee assigns to D in his moving target model. Nevertheless, fertility research has often overlooked this fact, mainly for two reasons: The lack of long time-series on this indicator and the apparent stability of its evolution over time. The interest in family size preferences has been recently renewed in connection to their decline below replacement levels in some countries (Goldstein et al., 2003), but as we will show in this chapter, even subtler changes at higher levels can explain strong variations in period fertility and deserve more attention.

Most of the research on fertility preferences has been focused on whether or not they can predict future fertility (see Heiland et al. (2008) for an extensive reference list). Morgan (2001) explains how the doubts about the usefulness of preferences and desires are partly due to the use of the fixed-target model and he advocates for a framework which takes into account how preferences change over time.

Hence, understanding how family size preferences are updated is key. Research on the determinants of preferences has focused on several sets of factors: the perceived costs and benefits of children, social norms, resources, and life-course transitions. Evidently, these factors are impossible to isolate in practice. Most important life-course transitions affect the availability of resources and change the perception of costs and benefits of children. Social norms emerge from and change with the experiences of individuals, including their cost/benefit perceptions and the resources that are available to them at different points in time.

Udry (1996) compares one-decision (fixed-target) models vs sequential decision (moving-target) models finding evidence of a sequential update of reproductive plans. Regarding the time when the update occurs he notes: "Since children only come in units, and since the total range of planned numbers of children is quite restricted, we should expect fertility plans to be insensitive to relatively small changes".

As Goldstein and Cassidy (2014) model implies, cohort preferences are updated according to period events. But according to Udry these events have to be powerful enough for individuals to abandon their preferences in favor of a smaller/larger target. Marriage and the transition to parenthood are obvious candidates for preference-changing events, as previous studies have confirmed (Freedman et al., 1965; Miller and Pasta, 1995; Engelhardt et al., 2009).

Considering these findings, we allow the initial value of D to be revised at the moment of important life-course transition. Agents develop their initial preference of family size at age 14 and they consider whether to update this value at the time of marriage/cohabitation and every time they have a child. To make this decision, agents asses the prevailing norms regarding family size at the time, represented by the simulated TFR[3].

We assume that the individual ideal family size is connected both to

[3]The interpretation of the TFR as the existing fertility norm is problematic given the limitations of this indicator we have listed above. For this reason we are currently working on a version of the updating mechanism that considers instead the average desired number of children of all agents within an age range of ± 5 from the main agent's age

prevailing social norms but also to individual preferences regarding family-work balance. Following this assumption the initial value of D comes from a different distribution depending on the family-work preferences defined in section 3.5.4. More precisely the ideal number of children D_i comes from a truncated gamma distribution:

$$D_{i,x} \sim \Gamma_{a \leq D_i \leq b}(TFR_c, \beta) \tag{3.1}$$

In this case we use gamma because it can be parametrized to resemble what one would theoretically expect from a distribution of desired number of children (positively skewed). Using a truncated distribution allow us to sample values from a specified range delimited by parameters a and b. Where $a = 0$ and $b = 2$ for women with a strong preference for a dual-earner household, $a = 1$ and $b = 3$ for women who allow different combinations of paid and unpaid work and $a = 2$ and $b = 7$ for women with a strong preference for a male breadwinner arrangement. The shape parameter of this distribution is given by the current level of the TFR, allowing for the feedback loop between social norms and individual preferences.

3.5.3 Childbearing

The reproductive trajectories generated in our model can be viewed as the result of a process in which individuals pursue the realization of their ideal family size against a series of constraints. This perspective allows us to explore the gap between the desired number of children and the number of children people finally have.

There is an extensive literature on the factors that depress fertility relative to desired family size. Bongaarts (2001) recognizes three factors: the rising age at childbearing, involuntary infertility and competing preferences. In fact these are sets of factors within which more specific drivers can be identified.

In order to keep our model as simple as possible we concentrate on a small set of mechanisms we consider essential and that will allow us to test the theories discussed earlier: The expansion of education, the formation of a union and the age at which this occurs, economic uncertainty and household-level gender equity.

At the individual level, the mechanisms described above act on individual's intentions to have a/an additional child. To operationalize this in the model, we equip our agents with an intention $I_{i,x}$. If an agent's preferences refers to the total number of children she would like to have, the intention reflects her more immediate plans to have a/an additional child. This intention is formed for the first time at age 14, but evolves in the course of an agent's life and it is shaped by a series of factors. We define it as:

$$I_{i,x} = \rho * E_{i,x} * U_{i,x} * R_c^{\alpha_j} * G_i^{\delta_j} * C_{i,x} \quad (3.2)$$

Where ρ is the baseline intention while the other coefficients represent each of the constraints listed above. The baseline intention can be interpreted as the intention to have a child free of constraints, for an agent who has the desire to have children. The value of ρ has to be estimated, with $0 < \rho < 1$.

The value of E varies depending on the agent's enrollment status: $0 < E < 1$ while the agent is enrolled and $E = 1$ after she finishes her education. Similarly, the value of U depends on whether or not she has formed a union: With $0 < U < 1$ before the event and $U = 1$ after. This set up allows for agents to have children outside unions and before completing their education, without assuming a fixed life-course path. In section 3.5.6 and 3.5.5 we provide details on how we model the transition out of the education system and the formation of partnerships.

R represents the perceived resources to afford a/an additional child and is given by a smoothed series of the unemployment rate, which we use to approximate the perception of agents regarding the economic situation at time c.

G represents the degree of conflict within the couple regarding the distribution of paid and unpaid work. The degree of conflict depends on the alignment of the preferences of the male member of the couple ${}_mP_i$ and the female member of the couple ${}_fP_i$ with respect to the time they are willing to devote to housework/childrearing:

$$G_i = \frac{1}{\exp(|{}_mP_i -_f P_i|)} \tag{3.3}$$

We consider three different types of preferences: Those agents (both males and females) with a preference for a male breadwinner type of arrangement, where most of the housework is done by the female ($P_i = 3$). Those with a preference for combining work and family, but who tolerate varying degrees of gender equity in the distribution of housework ($P_i = 6$). Finally, those with a strong preference for a symmetric distribution of housework ($P_i = 9$). The larger the disagreement between both members of the couple, the smaller the value of the coefficient thus the longer the waiting time to the first/next child. Section 3.5.4 provides details about the assignment of gender equity preferences.

We assume that the work/family conflict and the assessment of the resources available only start playing a role as individuals get closer to the time they will start a family, hence before the formation of a partnership we set $R = G = 1$.

The α and δ parameters depend on parity j and they control the weight given to the different effects. After the birth of the first child, these parameters allow us to increase the effect of the immediate constraints coming from the household dynamics and the availability of resources, following the evidence which shows that the key to low fertility in Europe is in second rather than in first births (Van Bavel and Różańska-Putek, 2010).

Finally, C is the distance between the desired number D and the children the agent already had K at a given age. If $D - K > 0$ then $C = 1$, if $D - K \leq 0$ then $0 < C < 1$. Which means that an agent that has already achieved her ideal family size has a lower intention to have an additional child than those that have not.

As in previous stochastic models of the reproductive process we use the exponential distribution as a model for the distribution of the random variable ${}_CT$, the waiting time to conception (Mode, 1985). The exponential distribution has probability density function:

$$f(t; \lambda_{i,x}) = \lambda_{i,x} e^{-t\lambda_{i,x}} \tag{3.4}$$

We let the intention $I_{i,x}$ defined above affect the risk with which agents experience a pregnancy. The relationship between the intention and the rate is such that the risk is proportional to the intention:

$$I_{i,x} = k\lambda_{i,x} \tag{3.5}$$

Realizations of ${}_CT$ are obtained by sampling from the probability density function above using the inverse distribution function (for an explanation of the method see: Willekens (2009)).

$$ {}_CT_{i,x} = \frac{-\log(u_{i,x})}{\lambda_{i,x}} \tag{3.6} $$

Where $u_{i,x} \sim \mathcal{U}(0,1)$.

Following Singh et al. (1974) we define the waiting time to the next birth ${}_CT$ as the sum of the waiting time to conception plus the length of gestation h_1 and postpartum sterile periods h_2 (for second and higher order births). The waiting time to first birth is assigned at age 14 and is given by:

$$ {}_{1B}T_{i,x} =_C T_{i,x} + h_1 \tag{3.7} $$

The pregnancy period is set in 270 days. For the case of second and higher order births we have:

$$ {}_{jB}T_{i,x} = h_2 +_C T_{i,x} + h_1 \tag{3.8} $$

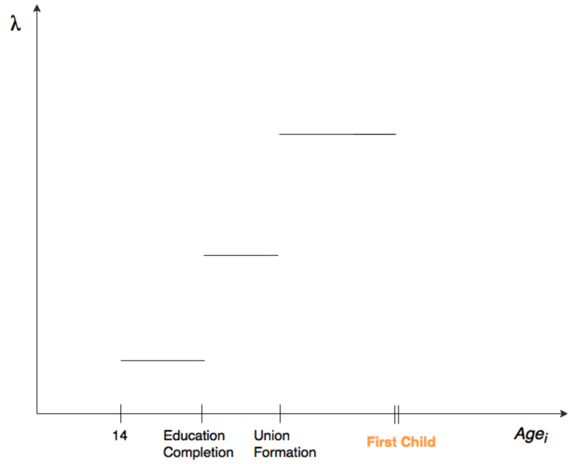
Where the inter-pregnancy period h_2 in months comes from a truncated normal distribution:

$$ h_{2,i} \sim N_{7 \leq h_{2,i} \leq 90}(28, 16) \tag{3.9} $$

For those agents who choose to remain childless ${}_BT_{i,t} = \infty$.

Figure 3.4 presents a stylized example of the evolution of the risk of a first pregnancy over the life course of a particular agent. The picture resembles one of a piecewise model where the jumps in the hazard of the transition are defined by relevant life course events in the transition to adulthood.

Figure 3.4: Transition Rate: First Child



The assumption here is that the risk of having a child depends less on an external measure of age than on a subjective perception connected to the achievement of relevant markers in the transition to adulthood. Two individuals of different age but with the same status regarding those transitions are exposed to the same risk of having a child, their waiting times to conception are sampled from an exponential distribution with same rate parameter.

Models Based on Fertility Intentions vs. Models based on Fertility Rates

A number of dichotomies have been used to define the difference between ABM and microsimulation: Explanation vs. prediction (Gilbert and Troitzsch, 2005), individual behavior vs. social interaction (Bae et al., 2016), static vs. adaptive agents (Miller and Page, 2009) or linear aggregation vs. feedback loops (Silverman et al., 2011). The emphasis given to one of the characteristics in these pairs reflects different origins, traditions and uses of ABMs and microsimulations. Nevertheless, nothing prevents a microsimulation model to include some of the features that characterize ABM, like feedback loops, agent's adaptation or interaction, and certain ABMs might be used for prediction without necessarily turning into something else.

A less explored, but probably more fundamental distinction is found in the *perspective* adopted in these two modelling traditions, which is expressed in the use of rates/probabilities vs. the use of rules to define a state change. Rules in ABMs are defined, not only at the individual level, but from an individual's *perspective*, as in Schelling segregation model when agents move after they become unhappy with the situation in their neighborhood. While the rule *makes sense* from the point of view of the actor, a rate or a probability is an aggregate quantity that exists only for the modeler.

As discussed earlier, the use of aggregate measures can restrict the interpretation of results in terms of individual behavior. Adopting a strong agent-based perspective, where the hand of the observer cannot be seen in the model, can guarantee a more direct connection between our results and its behavioral interpretation.

The way we model the decision to have a child here does not adjust to the deterministic "if x do y" type of rule common in classic ABM, as the intention does not determine the decision directly but the hazard of a probability distribution as seen above. This method developed in Klabunde et al. (2016) might provide less empirical structure than the use of observed rates but favors a more fluid modelling of the agent's perspective and it has the added benefit of not requiring large amounts of data.

3.5.4 Gender Equity

Given our interest in assessing the role played by gender dynamics on the evolution of the TFR, we classify our agents, as mentioned earlier, in three categories depending on their preferences regarding the distribution of unpaid work: those with a preference for a male breadwinner arrangement, those with a preference for an arrangement which combines work and family with varying degrees of gender equity and those with a strong preference for a dual-earner household.

As the literature on the subject shows, referring to women's roles as "preferences" might be deceiving in a large number of cases in which these roles are imposed by a series of forces (labor market dynamics, institutional settings, etc.) which leave no room for an open election between equally plausible alternatives. Nevertheless, this debate is not the focus of our paper, we use the word *preference* for lack of a better term but we are just interested in the roles women assume, whether elected or imposed, and most importantly, in the distance between the expectations of men and women.

As Esping-Andersen (2009) has shown, the substantive change in the role of women in the labor market has been accompanied by a parallel and equally impressive transformation in their educational credentials. From different analytical frameworks more equality of resources is expected to lead to more equality in the distribution of housework. Relative resources, together with time availability of the members of the couple, has proved to be one of the most important predictors of the gender gap in housework (Bianchi et al., 2000).

The picture that emerges from the analysis of long term time-use data shows indeed a process of equalization in unpaid work following women's educational revolution. However, this process is far less advanced than the narrowing gap in men's and women's relative productivities would predict and notably stratified by education level. Higher educated men show a larger contribution to home production relative to their less educated counterparts (Esping-Andersen, 2009). The specialized literature has linked the adoption of more traditional gender specialization among less educated women to lower opportunity costs and lower bargaining power but also to the effect of social norms.

Following these findings, we assume that agents with primary education or less will have a "preference" for a traditional male breadwinner arrangement. For those with secondary education, we assume that a proportion ${}_sp_c$ will have a preference for a household where work and family are combined with varying degrees of gender equity, while a proportion $1-{}_sp_c$ will favor a male breadwinner arrangement. The calibration of these proportions allows us to mimic the non-linear trend towards equalization described before. Similarly, a proportion ${}_tp_c$ of those with the highest education level are assigned a preference for a dual earner household and a proportion $1 -_t p_c$ a preference for the arrangement that combines work and family with less symmetry between partners.

Again, rather than the particular development of each type of preference, we are interested in reproducing the theoretical evolution of the level of conflict in the population as the "gender revolution" moves forward.

3.5.5 Union Formation

The transition into a union is modeled parametrically using the log-normal distribution. Models based on this distribution have been successfully applied to waiting time to marriage distributions in the past (Mode, 1985). The waiting time to union formation $_{U}T_i$ is obtained by sampling from a log-normal distribution where the mean and standard deviation depend on calendar time and educational level of the agent.

When a male agent is born he is assigned a preference for a type of work-family arrangement. When the time comes for a female agent to marry she chooses among the pool of available single males born up to 5 years earlier and 1 year later. This decision is governed by a vector of probabilities p_h which decreases as $|_m P_i -_f P_i|$ (the absolute value of the differences in their preferences) increases. The vector p_h controls the degree of homogamy with respect to preferences in the population.

3.5.6 Education Completion

The time agents take to complete their education depends on the level of education they attain. We consider three levels: Primary, secondary, and tertiary.

The waiting time to education $_{E}T_i$ is obtained from the number of years ye_i agents remain in the education system, which are obtained from a truncated normal distribution:

$$ye_i \sim N_{a \leq ye_i \leq b}(\mu, 3) \tag{3.10}$$

Where $a = 0$ and $b = 6$ and $\mu = 6$ for those with *primary* education or less; $a = 6$ and $b = 12$ and $\mu = 10$ for those with *secondary* education; $a = 12$ and $b = 30$ and $\mu = 16$ for those with *tertiary* education.

3.5.7 Death

The waiting time to death ${}_DT_i$ is also obtained using the inverse distribution function method. This time, instead of applying it to a parametric model we use age-specific cohort mortality rates from the Human Mortality Database as a piece-wise model of the mortality process in our simulated population. For the ages/years where information is not available we use the latest available figures. Missing data corresponds essentially to the most recent decades, when mortality of females under 50 years of age is low.

3.6 Software

The model is entirely built on R, using the igraph package to create a relational dataset (Csardi and Nepusz, 2006). Although in the current specification we do not incorporate social interaction, the set up allows for the modelling of network effects without having to resort to additional software.

The simulation is run in parallel using the snowfall package (Knaus, 2013). Using 6 cores in a standard laptop computer it is possible to simulate around 120.000 events in less than 60 minutes. Each individual simulation consists of 90 calendar years of events, from 1925 to 2014, and an initial population of 1.000 that grows to about 3.000 female agents.

3.7 Calibration of the Model Using Spanish Data

In this section we present the data and procedures used to calibrate the model to the Spanish case before we turn to the results.

To obtain the *initial age structure* of the population we use the 1940 Spanish census. For the *initial distribution of the population by education*, we use information from the 1970 census, which is the first to present disaggregated population figures and from the 2011 census for the same distribution during the years we run the simulation. All census data come from the National Statistical Office of Spain (INE).

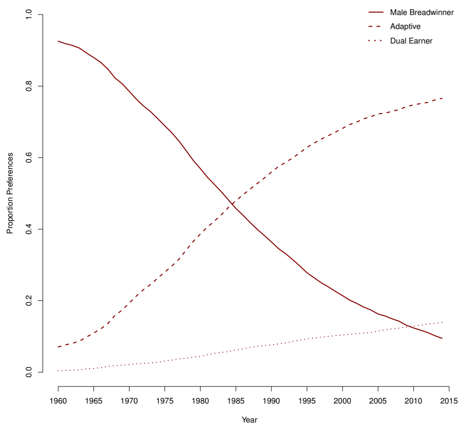
The age-and sex-specific cohort *mortality* rates from 1925 to 1984 for Spain were obtained from the Human Mortality Database.

Although we do not have complete data on the evolution of *gender preferences*, we rely on the theoretical description of how preferences should have evolved in order to explain the observed period fertility trends. This description is based on scattered data points and anecdotal evidence. According to Esping-Andersen (2009), by 2002 a quarter of women in Spain favored a traditional male breadwinner family. Similarly, Vitali et al. (2009) have applied Hakim (2003) classification to Spanish data from 2004, finding that 21% of women belonged to the family-oriented category, 66% to the adaptive group and 13% were career oriented.

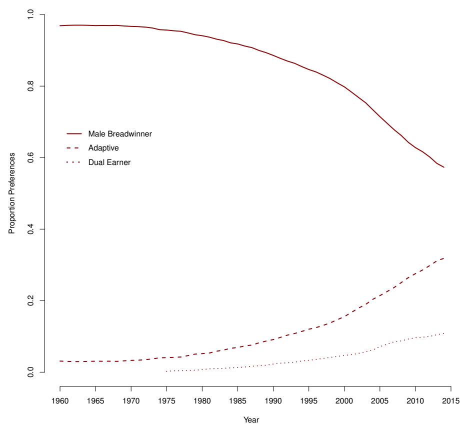
Taking into account the theoretical description and the evidence available we produce a plausible scenario presented in figure 3.5. In the case of females the proportion with traditional preferences declines quickly, following the collapse of the proportions of women that only achieve primary level education. Consequently, the proportion of women favoring a combination of work and family increases and becomes dominant by the 90s. In the case of males there is a similar trend, although delayed, which produces the hypothesized increase followed by a reduction of the household level conflict.

Preferences are assigned in connection to the agent's education level as explained in section 3.5.4. Male's preferences are also assigned by sampling with given probabilities. The manipulation of these vectors of probabilities allows us to generate scenarios for the evolution of preferences, including the one presented in figure 3.5.

Figure 3.5: Proportions of Women with a Given Preference, Ages 15-50 — 1960-2014, Spain.



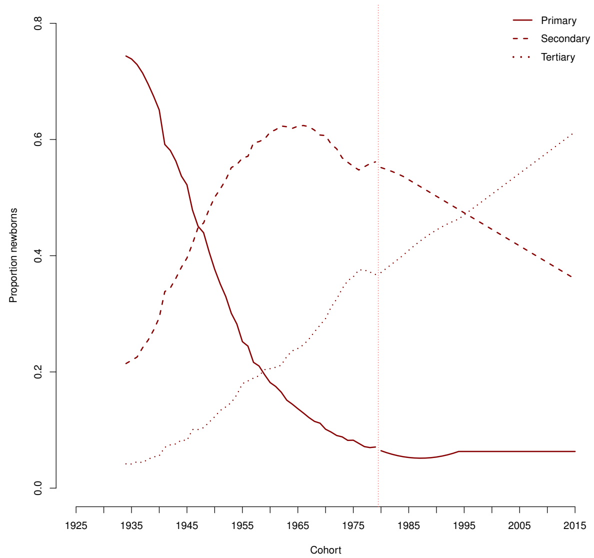
(a) Females



(b) Males

Information from the 2011 census is used to assign to the newborns in our model the *education level* they will attain. Figure 3.6 shows the proportions on each level by birth year, after 1980 we assume a continuation of the linear increase in the proportion achieving tertiary education, a linear declining trend in the share of women achieving only up to secondary education, and a stagnation in the share of women achieving primary education only (at under 10%).

Figure 3.6: Observed and Predicted Proportion of New Borns by Achieved Education level — Females, Spain.



The expansion of education among women is usually described by the increasing proportions achieving post-secondary levels. This trend can be clearly observed in Figure 3.6, although even more interesting is the collapse of the proportions achieving only primary education or less. While close to 70% of women born in 1940 studied up to a maximum of six years, ten years later that proportion had dropped to under 40% and twenty years later to under 20%. As we will show later, this collapse will be fundamental to understand the profound changes in the family formation dynamics observed in Spain from the second half of the 20th century.

3.8 Results

In this section we initially present the fit of the model to a set of aggregated observed outcomes and later the results of a series of scenarios which explore the relative role of different factors in the decline and recuperation of period fertility in Spain.

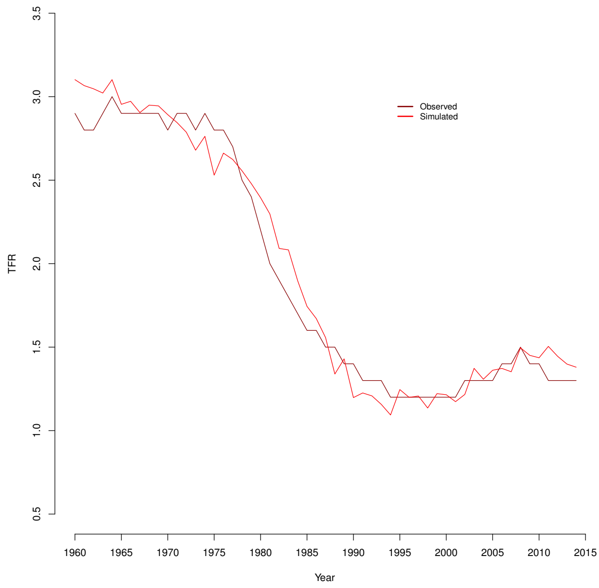
3.8.1 Model Fit

Figure 3.7 presents observed and simulated TFRs for our observation period. The model fits reasonably well considering the complex micro dynamics behind these aggregated trends. The fact that the model can reproduce the trend described by the TFR does not necessarily imply that individual reproductive trajectories in our simulated population are similar to those in our target population. Therefore, we also explore how the model behaves with respect to other relevant outcomes.

Figure 3.8 shows observed and simulated age-specific schedules from the first to the last available data. Here the fit is also acceptable, specially during the first twenty years. Towards the end of the nineties there is an increase or at least an unexpected stabilization of fertility at earlier ages due to the incorporation to the Spanish population of immigrant women with a markedly different pattern of childbearing.

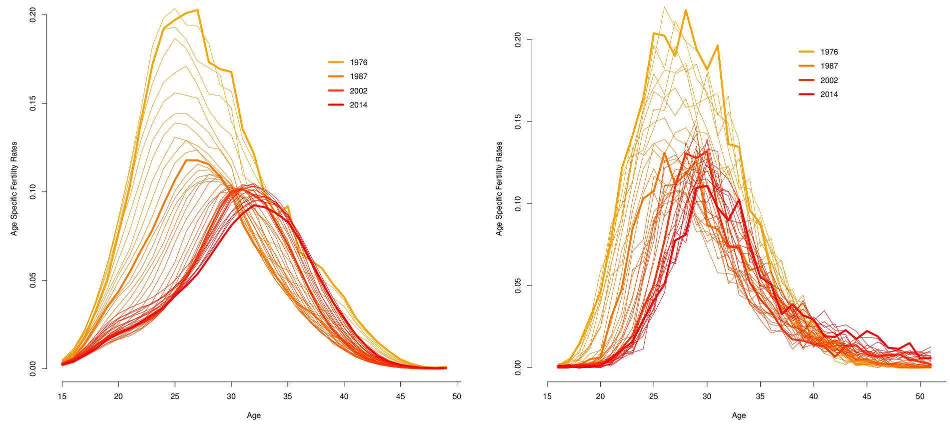
Figure 3.9 shows the observed and simulated evolution of the mean age at first birth. As we will describe later, the pattern of rapid increase followed by a stabilization since the late 1990s explain a significant part of the observed period fertility patterns. The sudden re-increase around 2008 is linked to the most recent economic recession.

Figure 3.7: Observed and Simulated TFR — 1960-2014, Spain.



Finally, figure 3.10 presents the proportions with given family size ideals produced by our model. These figures are close to the ones reported in Sobotka and Beaujouan (2014) (represented by points in the figure) and they show that, behind the apparent stability of family size ideals, there have been relevant compositional changes. In this case using an average can be misleading. A change like the one produced by our model (not shown) from about 2.7 to about 2.2 can give the impression of relative stability, while the number of women desiring larger families has declined considerably.

Figure 3.8: Observed and Simulated Age-Specific Fertility Rates — 1976-2014, Spain.



(a) Observed (b) Simulated

Figure 3.10: Proportions of Women with Given Ideal Number of Children — Ages 15-50, Spain.

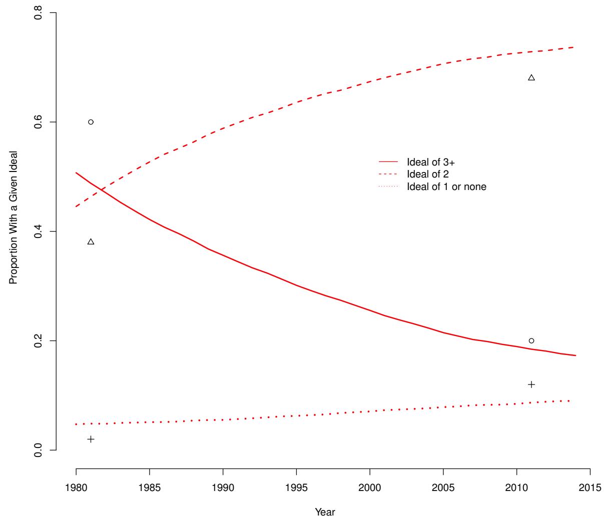
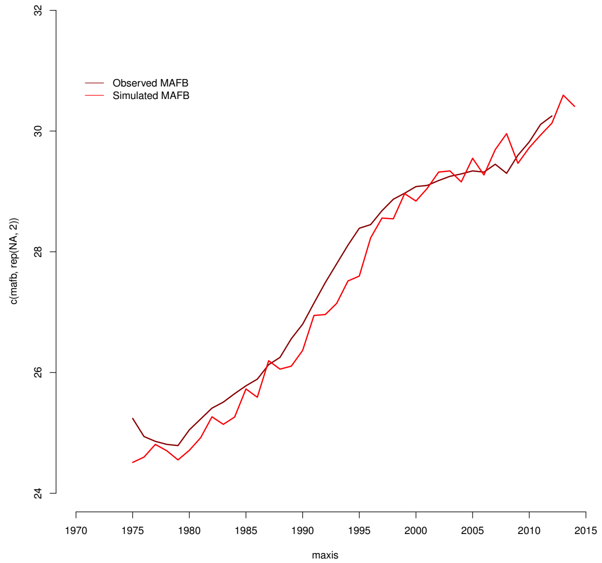


Figure 3.9: Observed and Simulated Mean Age at First Birth — 1975-2014, Spain.



3.8.2 Analysis: Scenarios

High Gender Equity

In order to test the role of gender dynamics we first present results from a scenario in which the evolution of men's preferences mimics that of women, resulting in a very low degree of conflict over the distribution of paid and unpaid work (Figure 3.11). Even in a scenario of matching preferences we still find the inverted J-shape pattern observed in the original model. At least in the current specification of our model, the steep decline from the mid 70s and the recuperation from the early 2000s are independent of gender dynamics. This does not mean, however, that gender equity does not play a relevant role, in fact, the conflict over the distribution of housework explains how low period fertility will decline and also the extent of its recuperation. In a world of matching preferences Spain would have never reached the extremely low TFR values experienced in the 90s and would be nowadays part of that group of countries with brighter prospects with respect to the pace of population aging.

Figure 3.11: Observed vs. Simulated TFR with High Gender Equity — 1960 - 2014, Spain.

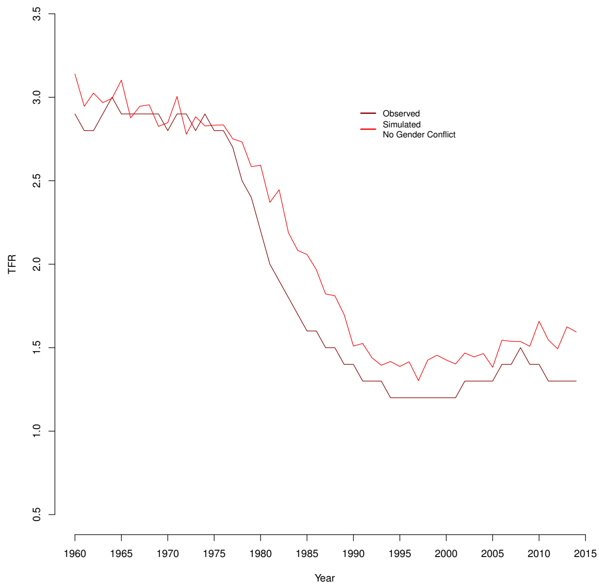
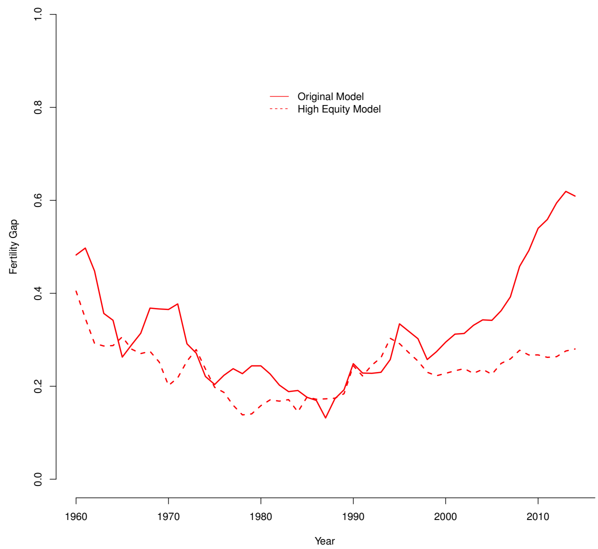


Figure 3.12 compares the fertility gap in the original vs. the high gender equity scenario. The gap refers to the average distance between the ideal and the actual number of children for all female agents with an ideal of less than three children. Until the 1980s the gap in both models is similar, which is mostly explained by the proportion of female agents who wish to become mothers but never form a union. The difference between the two models in the last three decades is the result of frustrated expectations of agents in the original model due to the effect of gender inequity and economic uncertainty. It is interesting to notice how the gap in the original

model continues to increase even at the time when period fertility shows a modest recovery, again pointing at the pure end-of-postponement effect. At the very end of the observation period the gap stops growing thanks to the closing up of the distance between male and female preferences.

Figure 3.12: Fertility Gap — 1960 - 2014, Spain.

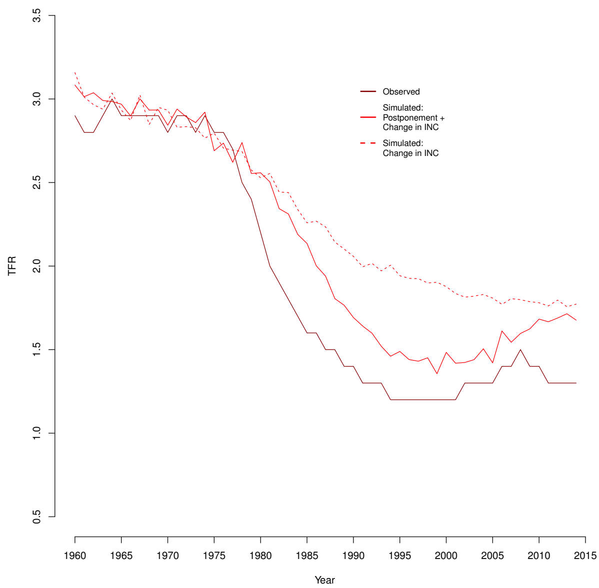


Compositional Changes + Postponement

Having explored the role of gender equity we now direct our focus to other factors that might have played a role in the evolution of the TFR. In figure 3.13 we present results from two different scenarios: One in which we consider only the effect of changing family size ideals and postponement, and a second one where only the former is considered.

One interesting conclusion that emerges from this exercise is that these two forces are enough to explain the U-shape or, more precisely, inverted J-shape pattern. According to our model the steep period fertility decline is a direct consequence of the effect produced by cohorts of women with modern family size ideals hitting their reproductive years by the mid 1970s in conjunction with a rapid and sustained postponement of the transition to parenthood. The combination of these quantum and timing effects accounts for the rapid pace of the decline. At the other end, the stabilization and recuperation (in period terms) are direct consequences of the slowing down of the pace of postponement, as demonstrated by the absence of recuperation in the model that assumes no change in the timing of childbearing (dotted line in figure 3.13). The mechanisms that connect a deceleration in the pace of postponement with a recuperation of period fertility have been described in detail in Bongaarts and Sobotka (2012).

Figure 3.13: Observed vs. Simulated TFR, Alternative Scenarios — 1960 - 2014, Spain.



A final interesting element to notice is how both models converge to a similar level of around 1.8 children per woman. The gap between this figure and the ideal number of children (an average slightly above 2) is explained by the assumption that a proportion of around .15 of the population never marries. It is likely, however, that in a world without gender inequities and economic uncertainty this proportion would be lower and the level of period fertility closer to replacement.

3.9 Conclusions

One of our main goals was to test the hypothesis that connects fertility decline and recuperation with an increase and subsequent decrease in the amount of conflict over the gendered division of labor within households. As described earlier, this emerging narrative depicts the evolution of period fertility as a general trend towards "less family" resulting from frustrated expectations followed by a trend to "more family" as women's and men's preferences re-align.

After experimenting with our model we conclude that the lack of gender equity and the uncertainty over resources can produce a substantial gap between ideal and achieved fertility, but the emergence and subsequent closing of this gap cannot explain the observed pattern of decline and recuperation of period fertility, at least in Spain.

The U-shaped pattern showed by period fertility rates is in fact the result of a combination of postponement and compositional changes with respect to family size ideals. The collapse of period fertility rates was brought about as the cohorts of women who experienced radical improvements in educational attainment since the 1940s started replacing cohorts with more traditional preferences (with respect to both quantum and tempo) by the 60s and 70s.

The role of postponement and tempo distortions on the TFR has been extensively studied but the role of family size preferences has received less attention. This is probably a result of the lack of historical data and of the apparent stability of preferences over time. We showed, however, how important distributional changes in the proportions of women with different family size ideals where still taking place simultaneously with the beginning of postponement. These changes, that could appear modest when looking at average indicators, explain a significant fraction of the decline of period fertility in the second half of the twentieth century. Nevertheless, family size ideals remain above replacement throughout the process, therefore the description of this process as a move towards "less family" can be misleading.

Even though our analysis of alternative micro-level dynamics provided little support to the idea that gender dynamics are the fundamental driver of the observed U-shape trends in period fertility, the degree of conflict over the gendered distribution of paid and unpaid work in a country seems to be one of the key factors explaining the difference between those countries that have achieved close to replacement fertility and those that remain in a zone of period fertility rates below 1.5 children per women.

In any case, at least in the current version, our model is better suited to obtain qualitative insights regarding the general shape and pace of trends and its generating micro-level dynamics than to provide precise estimations of the different quantities analyzed.

Among the many potential improvements to be introduced in our model we highlight the need to endogenously generate the union formation process as well as the formation of preferences, which should be a dynamic result of the interaction with present conditions (degree of preference alignment, economic situation) at each stage.

Beyond our substantive conclusions the analysis show, once again, the risk of trying to extract conclusions about individual family formation decisions from the the evolution of the Total Fertility Rates. This indicator shares the limitations of other fertility measures and models resulting from the discrepancy between how data is organized and analyzed and how the reproductive process is actually experienced by individuals in the real world. This tension poses problems for the interpretation of models and measures from a behavioral angle.

In this context, agent-based computational approaches might represent an important contribution. The ability to give systematic treatment to key but unobserved/unobservable factors is one of its main advantages, expanding the range of questions that can be explored, as was shown here regarding the effect of gender role attitudes on period fertility trends.

An additional advantage of this approach is the possibility to model complex dynamics, as the ones emerging from the interaction of the micro and macro levels. The feedback loop between individual decisions and social norms regarding family size was, for instance, a key dynamic in the explanation of our results that would have been difficult, if not impossible, to take into account using an alternative modelling approach.

Finally, the consolidation of ABM as a standard tool in demographic analysis will likely contribute to solve some of the difficulties arising from the above-mentioned tension between the organization of data and the individual experience. Forcing us to adopt the perspective of individuals ABM can provide a stronger behavioral foundation to fertility models.

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CONCLUSIONS

3.10 Understanding the Fertility Gap

The three chapters included in this dissertation aim to improve our understanding of the characteristics of individuals and couples making fertility decision across their life course. These decisions refer to the number of children but also to the timing of each new birth and together they comprise the aggregate indicators that researchers use to analyze population dynamics. By now, however, we know well that knowing the characteristics of each person is not always enough to understand the process that results from the aggregation of their individual decisions. This dissertation, therefore, makes further attempts to improve our understanding of the connection between the individual and the aggregate, paying particular attention to their dynamic interaction.

With respect to individual characteristics, all three chapters present evidence showing how individuals who feel insecure about their employment situation or about the state of the economy tend to delay their childbearing plans and tend to have a lower number of children. This is a particularly relevant conclusion in a context in which an important number of economies in Europe have been systematically failing to provide stable employment prospects for an increasing fraction of workers. A state of affairs that will hardly improve judging by recent projections regarding the automation of increasing segments of the labor market (Frey and Osborne, 2013).

In our first chapter we showed how considering all the available information about the employment trajectory of an individual instead of isolated events can improve our understanding of the impact of economic uncertainty on fertility decisions. Nevertheless, the precise estimation of this effect is still a challenge. Detailed information on labor market trajectories almost exclusively refers to individuals most of the time, making impossible to consider relevant couple dynamics.

Another characteristic that proved to be essential throughout our analyses was the level of education attained by individuals. To this respect we confirm what several previous studies have shown: Individuals that spend a longer period of time in the education system tend to delay childbearing. Although there is a less defined general relationship with respect to the total number of children, the postponement process observed in the past decades in most European countries significantly affected the most common fertility indicator, the TFR, contributing to create the impression, at least temporarily, that an important transformation of fertility levels was taking place as well.

The transformations in the education system will likely continue to affect demographic behaviors even if the expansion of educational attainment stabilizes. Agent-based models are starting to explore the transformation of traditional gender dynamics in the marriage market as a result of the reversal of gender inequality (Grow and Van Bavel, 2015). This process will likely have a significant impact on future fertility trends which could be analyzed with the model of the reproductive process presented here in chapter 3.

Another characteristic, this time of the couple, that seems to explain variation in individual fertility outcomes is the degree of symmetry of the preferences of both members of the couple regarding the distribution of paid and unpaid work. The analysis presented here support the argument made by other studies that couples with lower degrees of conflict regarding expected household roles tend to have less difficulties to have children. This dynamic, however, is not limited to the households. The degree of tension between the roles of parent and worker depends as well on the organization of other social systems and institutions such as the educational system, the labor market and the health system, among others.

The extent of the relative contribution of factors like economic uncertainty or educational attainment to fertility change might be subject to debate, but there is a wide consensus about their importance, which is reflected in the large number of studies dealing with these issues. A more original contribution of this thesis is reflected in our conclusions regarding some of the *mechanisms* behind the evolution of aggregate fertility trends.

As our analysis of fertility postponement in chapter 2 shows, the consequences of a change that affects some of the determinants of the childbearing decision can be amplified by the effect of social interaction as people tend to imitate what their friends and colleagues do. Since this mechanism cannot be encapsulated in a single, observable individual characteristic it is usually left behind in traditional modelling approaches. This is an important limitation of statistical models, as our own analysis showed, the influence of social interaction can be greater than that of any individual attribute.

Social interaction occurs horizontally, as when we imitate what our friends do, but also occurs vertically, as when we relate to previous generations and other members of our community through the norms and institutions they contributed to create. Traditional statistical tools are not very well suited to analyze this type of recursive interaction between aggregate norms and individual behavior, although they are key to understanding any process of social change. This heritage in the form of norms determines to a great extent the limits of our own choices.

Modelling the dynamic interaction of individual behavior and social structures allows for a direct connection with the way in which contemporary sociologists understand social action. Theories that explain how Individuals do not make decisions in a vacuum have existed for a long time, now this is no longer a necessary assumption of our models.

Taken together, the results of the different chapters support the idea that reproductive trajectories are a complex process that resist reductionist approaches. This complexity is indeed one of the most interesting features of fertility analysis, because it inevitably leads to a systemic approach in which understanding how different social systems are organized (education, labor market, the welfare structure, etc) is key to predict how the reproductive process will be structured in a given time and place.

The fertility gap is the distance between our desires regarding when and how many children we want to have and what we finally achieve. This distance, as many others, depends on our ability to create more efficient and fair social structures.

3.11 New Modelling Approaches to Reproductive Decision Making

The other recurring topic of this dissertation is the attempt to improve the ways in which we model fertility decisions. Beyond our substantive results we hope these three chapters stand as relevant examples of the potential contribution of new modelling techniques to the analysis of social phenomena. A particularly interesting development in this regard is the recent emergence of a hybrid modelling approach which combines the flexibility and complexity of ABM with the empirical anchorage of microsimulation, while making use of tools and techniques from stochastic modelling and network analysis, like the model presented in chapter 3. There are very good reasons to expect computational models of this kind to become the predominant tool of analysis in various disciplines in the coming years.

The advance of the computer revolution continues to radically alter the ways in which researchers produce scientific facts. In a practical level, computers have contributed to the acceleration of the scientific process by shortening the time needed for certain stages of a research project and will continue to do so through the computerization of a rapidly increasing number of scientific tasks (Honavar et al., 2016). The computing revolution made possible for individual researchers or small teams to do what entire government agencies were doing 20 years ago, and it is still under way. Innovations like quantum computers promise to take computing speed to a level it was not possible to imagine just a few years back, while storage capacity still grows at an impressive pace.

In a more substantive level, computational modeling and simulation has transformed and is swiftly replacing mathematical models in various disciplines, expanding the scope and changing the nature of the scientific inquiry (Lenhard, 2015; Ruphy, 2015). From the philosophy of science it has been argued that computational modeling and simulation is the most influential technology since the second half of the 20th century, which has resulted in algorithms increasingly taking the space traditionally occupied by mathematics as the formal framework of various scientific disciplines (Douglas, 2015; Honavar et al., 2016).

According to Gilbert and Troitzsch (2005) computational models might be a *better* tool than mathematics for formalizing problems in the social sciences due to the less abstract and more expressive nature of programming languages and their ability to deal with parallel processes without a well defined order. Besides, the possibility to model heterogeneous agents and their modular organization makes computational models specially suited to tackle complex phenomena like most of the observed in the social world.

In this context it is likely that the computer-aided dynamic modelling becomes the standard in demography and in other social sciences, relegating statistical modelling to an ancillary position as a tool to assist in the calibration and validation of dynamic computational models.

For a long time, demographers have worked with quantities that often do not have a connection with how individual experience demographic events, at least in fertility research. The literature discussing the plunge of the TFR as an indication of dropping fertility levels provides a good example of this limitation. The popularization of models centered on agents might help rethink the way in which demographic information is usually organized and analyzed.

The potential growth of dynamic modelling and scenario simulation could also help improve key areas like policy evaluation and forecasting. The flexibility provided by agent-based models and their modular nature makes them a particularly interesting tool to progressively capture the systemic dimension of fertility decisions and opens a number of spaces for collaboration with specialist in different areas, like the labor market, the educational system, the welfare state, etc. This is an interesting potential direction in which to take our work, grounded on the belief that the ability to predict the future development of fertility indicators will only come from an understanding of the organization and evolution of the different social systems and institutions that structure the life course of individuals in contemporary societies.

In sum, as it is usually the case with the adoption of powerful technologies, the popularization of ABM will likely produce a qualitative change in the discipline. The same way astronomy would make great advances if anybody could have a space telescope on their desks, we will probably witness a quantum leap in demography as more and more virtual laboratories are set up in the coming years.

To conclude, we only wish that having reached this point the reader is convinced that we know more than ever about the mechanisms behind the evolution of recent fertility trends and that this dissertation has to a modest extent contributed to that state of affairs. But more important than what we currently know is what lays ahead. If the emerging methodological, epistemological and technological shifts we reviewed here become a reality in the coming years, an interesting future awaits for those interested in understanding the drivers of reproductive decision-making.

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