Micro-Level Mechanisms Behind the Decline and Recuperation of Period Fertility in Spain

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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 aggregated outcomes, but the micro-level evidence remains scarce and inconclusive. An alternative narrative has been proposed 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. While most accounts have remained at the macro level 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 understand 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.

Contents

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 in the last decades of the past century became clear and researchers started looking for theories that could explain both the long decline and subsequent recovery of total fertility rates.

At least three types of such theories can be identified in the demographic literature. The first one 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). A less general theory sees 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 the initial conflict generated at the couple level by the changing gender roles and its progressive reduction as institutions and households become more egalitarian. The third of these accounts is more strictly demographic, it highlights the role of postponement and its deceleration. According this perspective, the increase in period fertility is largely a result of diminishing tempo distortions while indicators of fertility quantum have remained relatively stable (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. We also aim to illustrate some of the advantages of ABMs over more traditional modeling techniques. First, we describe the model in detail and we situate it in the context of previous modeling efforts, then we calibrate it using Spanish data in order to test hypotheses related to the decline and recuperation of period fertility.

2 Theories of Fertility Decline and Recuperation

The move towards greater gender equity has become one of the key explanatory factors of observed fertility trends in industrialized countries. McDonald (2000) suggested that the very low levels of fertility observed 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) fertility or remaining in a low fertility scenario. More recent accounts, however, give gender dynamics a more central role. placing it as the fundamental driver of both period fertility decline in the second half of the 20th century and its recuperation in the last years (Esping-Andersen and Billari, 2015; Goldscheider et al., 2015; Anderson and Kohler, 2015).

Although some of the mechanisms identified by the authors are different, the underlying narrative is essentially the same: The steep period fertility decline post baby boom in most advanced economies 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 account, 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 is completed in some countries.

This argument is largely based on the apparent reversal of the negative correlation between period fertility and a series of indicators the macro level, like 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 Sobotka (forthcoming) the U-shaped pattern of change which has stimulated the reversals narrative is essentially a result of tempo distortions on the Total Fertility Rate (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 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 the increase of the TFR if mostly driven by a slowing down of the postponement of the mean age at birth. Rindfuss et al (forthcoming) have highlighted the formation of two clearly separated regimes, with a group of countries descending and remaining in the low fertility zone, while another group exhibits less problematic-close to replacement levels. Instead of a dominant factor type of explanation, Rindfuss et al (forthcoming) point to the complex array of institutions in place in each country to explain their membership to one of the two groups.

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

Although models are widely used in fertility research, most of these are what Burch (2003a) calls *empirical* models, a statistical device used to represent the structure of a specific set of data. Burch differentiates the modeling of a specific data set from the modeling of theoretical ideas. Theoretical (as opposed to empirical) models aim to capture the dynamics of a real-world system, exposing the mechanisms that lead to the emergence of a particular phenomena.

Although demographers tend to assume data and empirical models are closer to reality, many theoretical models allow for the introduction of variables that are key but unobservable or for which data is unavailable, providing a better representation of a particular system than any statistical version.

But even this distinction between theoretical and empirical models has to be revised. In various disciplines Agent-based models are increasingly combined with other techniques, moving beyond their purely theoretical/explanatory origins. In demography, we are witnessing the emergence of a generation of hybrid models combining microsimulation, stochastic models and ABM ((Bijak et al., 2013; Murphy, 2003),Willekens, forthcoming).

Another sharp line that can be found in fertility modeling is the one separating formal and behavioral models. 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. In fertility research models of the "formal" kind have received most of the attention, specially those dealing with cohort-period translation issues. The relatively marginal position of behavioral models can be seen as another consequence 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 seems to be based only in the degree to which the interpretation of the model makes explicit reference to the experience of individuals.

Indeed, a stronger behavioral foundation is one of the advantages highlighted by advocates of the cohort approach in fertility analysis. Ryder's answer to the question of why one should bother with cohort computations puts it in the most simple but powerful way: *it is the way people live.* [1].

Nevertheless, the problem of representation of the individual reproductive experience might not lie in the adoption of a period or cohort approach but in the way our measures/models are built.

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. 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 evolution of D is the driving force of Lee's model since he defines the annual birth rate to be proportional to the additional desired fertility (the gap between D and the fertility already achieved). 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. This "cumulative deficiency" makes sense from the modeler point of view but not from the individual's, couples clearly don't think what fraction of a baby they have lost at each-age when the decide to have another child. Individuals do not think in terms of rates.

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. Clearly, 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

[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`

extremely useful (it is in fact one of the most direct influences of the model we present here), the point here is that sometimes it is hard or impossible to translate the relationships between aggregate quantities into plausible individual decision-making mechanisms.

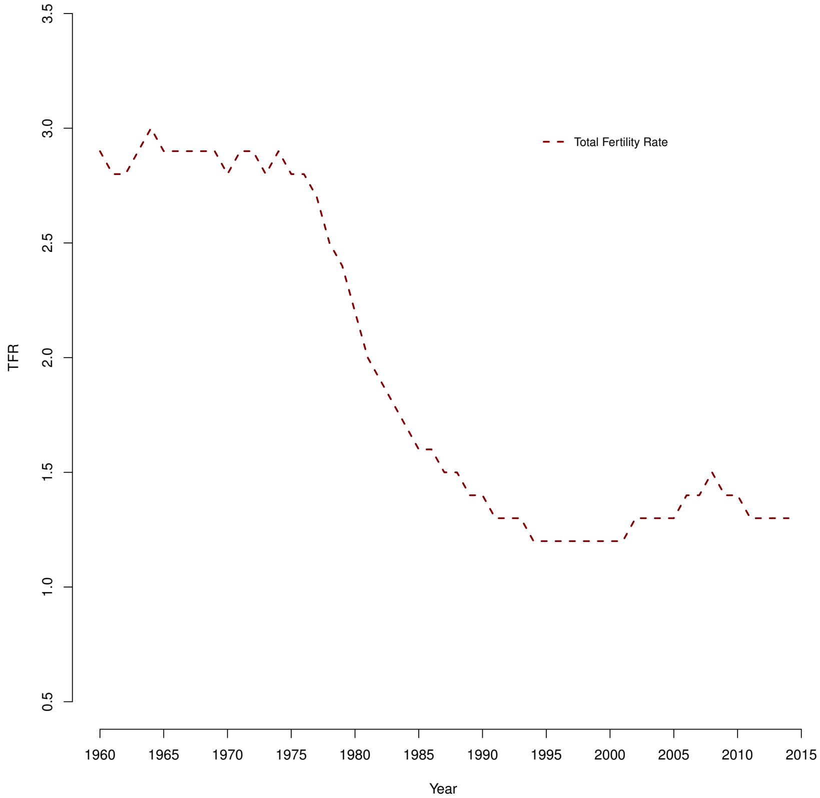
Discussing the problem of reification in Demography, and in fertility in particular, Wilson and Oeppen (2003) show with a series of examples how the behavioral assumptions behind demographic measures are rarely made explicit. Their analysis leads them to an extremely relevant observation: "Perhaps we 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?".

In the following we will try to show how modeling at the agent level can help close this gap between models and individual behavior, improving our understanding of demographic phenomena.

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 1 present 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 2000s period fertility experiences a small recovery until it falls again in the context of the last great economic recession.

Figure 1: Total Fertility Rates | 1960-2014 Spain.

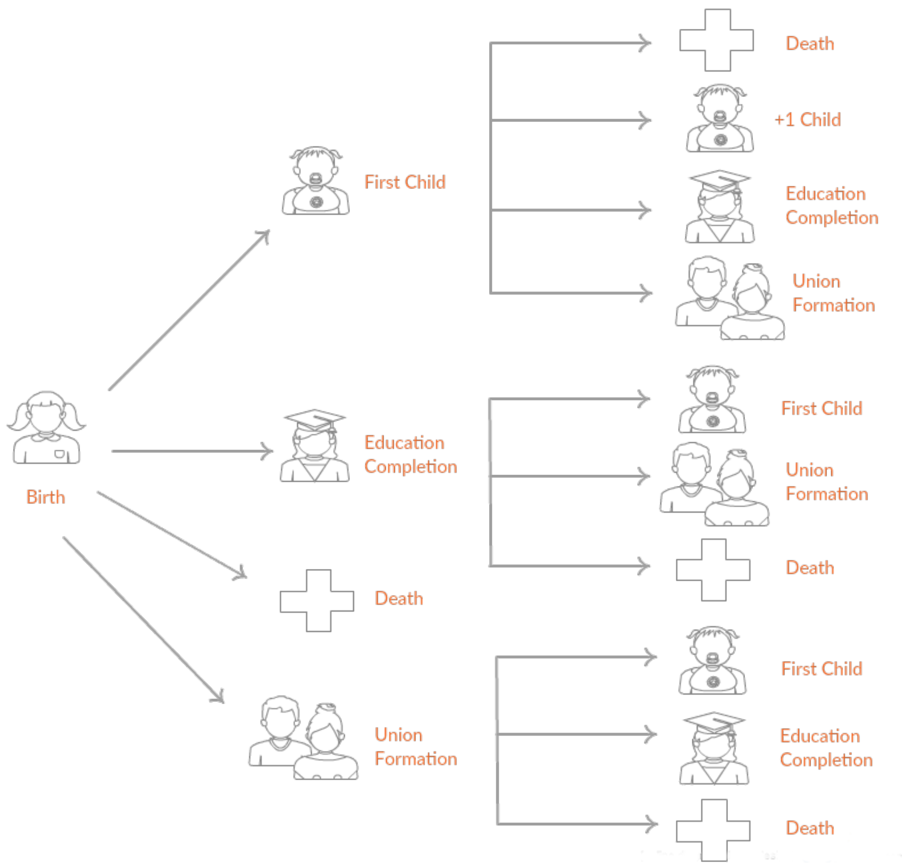


Sources: National Statistical Institute of Spain.

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 different 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 in 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 2 presents the state space and the set of potential transitions in our model.

Figure 2: States and Possible Transitions.



Our simulated individuals follow different paths, although 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 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 modeling such dynamics exceed the scope of this article. For the time being, it remains at the top of the queue of potential model upgrades.

Table 1 summarizes the characteristics of the female agents.

Table 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: "married/cohabitation"
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 the Completion of Education	${}_ET$	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)

5.1 Time

The model treats time as a continuous variable. Among the advantages of continuous-time models listed in Willekens (2009) we highlight the possibility to embed our simulation exercise in the event history analysis framework, accessing the tools and techniques of survival analysis in continuous 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 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 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 25 and 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 ${}_UT$, the waiting time to the completion of education ${}_ET$ and the waiting time to death ${}_DT$ are assigned at birth and remain unchanged until the event or until the agent dies before experiencing other scheduled events.

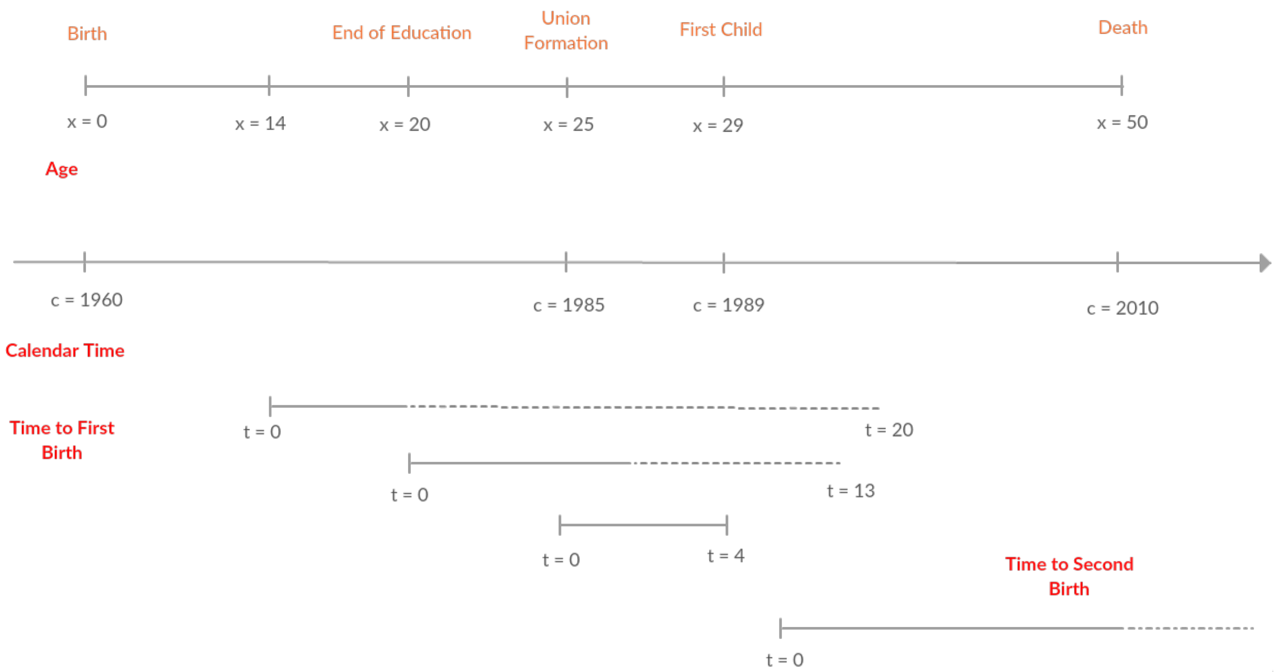
The time to the j^{th} birth ${}_{B_j}T$ is assigned at age 14 when the agent develops the intention to have a child. In section 5.2 we describe in detail how this intention works and which are the factors that can affect it, for now it suffices to say that the stronger the intention the shorter the waiting time. We assume that most agents prefer to complete important life course transitions (complete their education and finding a partner) prior to transitioning into parenthood. Therefore, before experiencing these events most agents have a relatively vague intention to have a child at some point in the future. After they start achieving other relevant markers in the transition to adulthood agents update their intentions as the event horizon gets closer.

In our example of figure 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 finish her education. A new waiting time is produced, but this one 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 here is that when agents revise their intentions after each life course event, they also update their desires 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 ins section 5.2).

[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.

Figure 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 which contains the set of all possible events from 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. Generating parallel life courses in that manner, allows for the introduction of social interaction/network effects.

By the end of a calendar year a series of aggregate indicators are computed from the life histories generated up to that moment. These indicators are used later to asses the model fit.

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, even more subtle changes at higher levels can explain strong variations in period fertility and deserve more attention.

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

Hence, understanding how family size preferences are updated is key. Research on the determinants of intentions 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 plans are updated according to period events. But these events have to be powerful enough for individuals to abandon their intentions 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. We use the TFR to represent this existing social ideals, ideals that encapsulate the different forces (cohort and period) shaping the reproductive process at a given time [3].

[3] An alternative measure could have been used for the update of D, like the average family size of the members of an agent network that have completed fertility. Although this might have a more direct connection with the agent's perspective, it also fails to capture the most immediate changes on family size ideals

We assume that the individual ideal family size is connected both to 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 5.4. More precisely the ideal number of children D_i comes from a truncated gamma distribution:

$$D_{i,x} \sim \Gamma_{a \leq D_i \leq b}(TFR_c, \beta) \tag{1}$$

Where $a = 0$ and $b = 2$ for career oriented women, $a = 1$ and $b = 3$ for adaptive women and $a = 2$ and $b = 7$ for family oriented women. 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.

5.3 Childbearing

Understanding the gap between the desired number of children and the number of children people finally have is one of the fundamental challenges for fertility research in post-transitional societies. Therefore we represent the reproductive trajectories in our model as a process in which individuals pursue the realization of their ideal family size against a series of constraints.

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.

[Section on fertility constraints]

In order to keep our model as simple as possible we concentrate on a small set of mechanism we consider essential: 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 to have a child $I_{i,x}$. This intention evolves in the course of agent's lives and is formed for the first time at age 14.

$$I_{i,x} = \rho * E_{i,x} * U_{i,x} * R_c^{\alpha_j} * G_i^{\delta_j} * C_{i,x} \tag{2}$$

Where ρ is the baseline intention while the other coefficients represent each of the constraints listed above. Therefore, the baseline intention can be interpreted as the intention to have a child free of constraints for those agents who have 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. While the agent is enrolled $0 < E < 1$, after she finishes her education $E = 1$. 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 of unions and before completing their education, without assuming a fixed life course path. In section 5.6 and 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:

$$G_i = \frac{1}{\exp(|{}_mP_i -{}_f P_i|)} \tag{3}$$

We consider three different preferences for the type of gender dynamics within the household: Those agents (both males and females) with a preferences 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 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 sill start a family, hence before the formation of a partnership $R = G = 1$.

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, the parameters they allow us to increase the effect of the immediate constraints coming from the household dynamics and the availability of resources, following the evidence that shows that they 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 $D - K = 0$ then $0 < C < 1$. Which means that agents that have achieved their ideal family size have 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:

$$f(t; \lambda_{i,x}) = \lambda_{i,x} e^{-t\lambda_{i,x}} \tag{4}$$

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:

$$I_{i,x} = k\lambda_{i,x} \tag{5}$$

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

$${}_CT_{i,x} = \frac{-\log(u_{i,x})}{\lambda_{i,x}} \tag{6}$$

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

Following Singh et al. (1974) we define the waiting time to the next birth ${}_{C}T$ 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:

$$ {}_{{}_1B}T_{i,x} = {}_C T_{i,x} + h_1 \tag{7} $$

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

$$ {}_{{}_jB}T_{i,x} = h_2 + {}_C T_{i,x} + h_1 \tag{8} $$

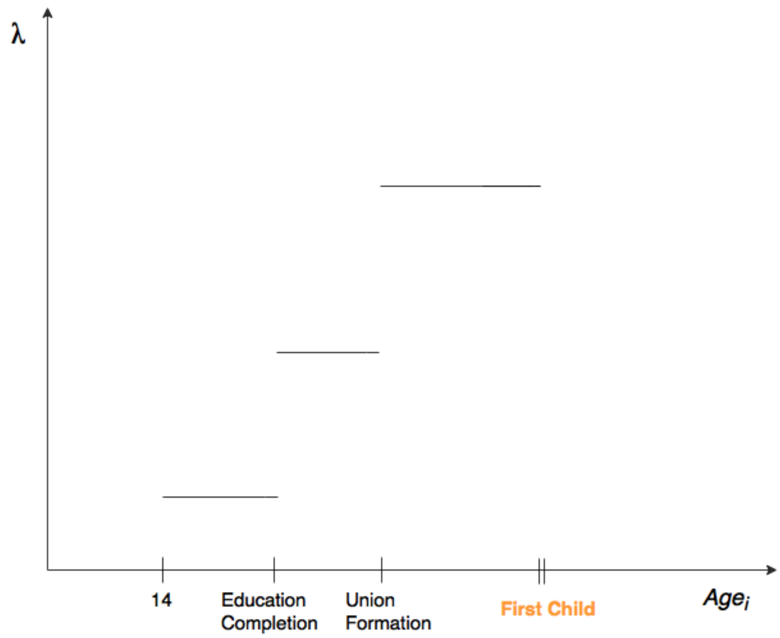
Where the inter-pregnancy period h_2 in months comes from a truncated normal distribution:

$$ h_{2,i} \sim N_{7 \leq h_{2,i} \leq 90}(28, 16) \tag{9} $$

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

Figure 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 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. In other words, their waiting times to conception are sampled from an exponential distribution with same rate parameter.

5.3.1 Models Based on Fertility Intentions vs. Models based on Fertility Rates/Probabilities

Sometimes the boundaries between agent-based models and microsimulation appear to be blurry. Microsimulation technically allows for the introduction of some of the features that characterize ABM, like feedback loops, agent's adaptation or interaction. In fact, for the most part the distinction reflects different origins, traditions and uses, more than fundamental differences between the two. However, we believe there is a substantive difference that lays in a simple but key element: the use of rates/probabilities vs. the use of rules.

Although this might seems a technical issue, it is far from being so. 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. 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 and it is evidence of its existence.

The presence/absence of supra individual forces in the systems we design, has implications for our ontological views on how the world operates, but that goes beyond the scope of this article. A more practical matter is that of interpretation. As discussed earlier, the use of aggregate measures can restrict the interpretation of results in terms of individual behavior and might lead to reification of our measures. Adopting a radical individual 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.

If we can make the case for its existence from an agent point of view, aggregate quantities can still be used in ABMs. A set of age-specific rates, for example, can be validly interpreted as social influence, the degree of social pressure to have a child that an individual receives at different moments of its life. But even in that case the rate is not a "pure" measure of social influence, as it summarizes the information from groups of individuals with different characteristics. If we are, as we usually are, interested in how some of these characteristics affect the decision to have a child, the obtention of these probabilities net of other effects becomes a problem of data. As Bijak et al. (2013) put it: "Unfortunately, as simulations become more complex and the state spaces of these models become larger, they require ever-greater quantities of data in order to define such probabilities, and collecting such data is time consuming, expensive, and in some circumstances may be completely impractical".

Rules tend to be deterministic, but this is not the essential issue, the essential issue is one of perspective. In that sense, our use of intentions resembles more the modeling approach in ABM than in microsimulation. Including the benefit of not requiring large amounts of data.

5.4 Gender Equity

Given our interest in testing the hypothesis that connects the decline and recuperation of fertility with an increase and stabilization of the conflict regarding family-work balance within the household, we focus on the degree of symmetry of the preferences of both members of the couple regarding the distribution of unpaid work.

As the literature on the subject demonstrates, referring to women's roles as "preferences" might be deceiving in a large number of cases in which this 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 shown earlier, we classify our agents between 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 regarding the distribution of houseworks and those with a strong preference for a dual-earner household.

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 it is expected that more equality of resources will lead to more equality 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 unpaid work 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 will predict and notably stratified by education level, with higher educated men having 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 of less educated women to lower opportunity costs and to lower bargaining power but also to the effect of social norms.

To simplify things, we assume that agents with primary education or less will have a preference for a traditional male breadwinner arrangement. From 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 $1 -_s p_c$ will favor a male breadwinner arrangement. The calibration of this proportions allow 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 the evolution of the level of of conflict in the population arising from gender dynamics.

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). A model based on the log-normal distribution offers an adequate fit to the available empirical distributions of age at first marriage in Spain.

When a male agent is born they are 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 later. This decision is governed by a vector of probabilities p_h which decreases as $|_m P_i -_f P_i|$ increases. The vector p_h controls the degree of homogamy with respect to preferences in the population.

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 $_E W_i$ is obtained from the number of years ye_i agents remain in the education system, which are obtained from a truncated normal distribution:

$$ye_i \sim N_{a \leq ye_i \leq b}(\mu, 3) \tag{10}$$

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.

5.7 Death

The waiting time to death $_D W_i$ 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 last available figures. Missing data corresponds essentially to the most recent decades, when mortality of females under 50 years of age is low.

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 modeling 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. With each individual simulation consisting on 90 calendar years of events, from 1925 to 2014, and an initial population of 1.000 that grows to about 3.000 female agents.

7 Calibration of the Model Using Spanish Data

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

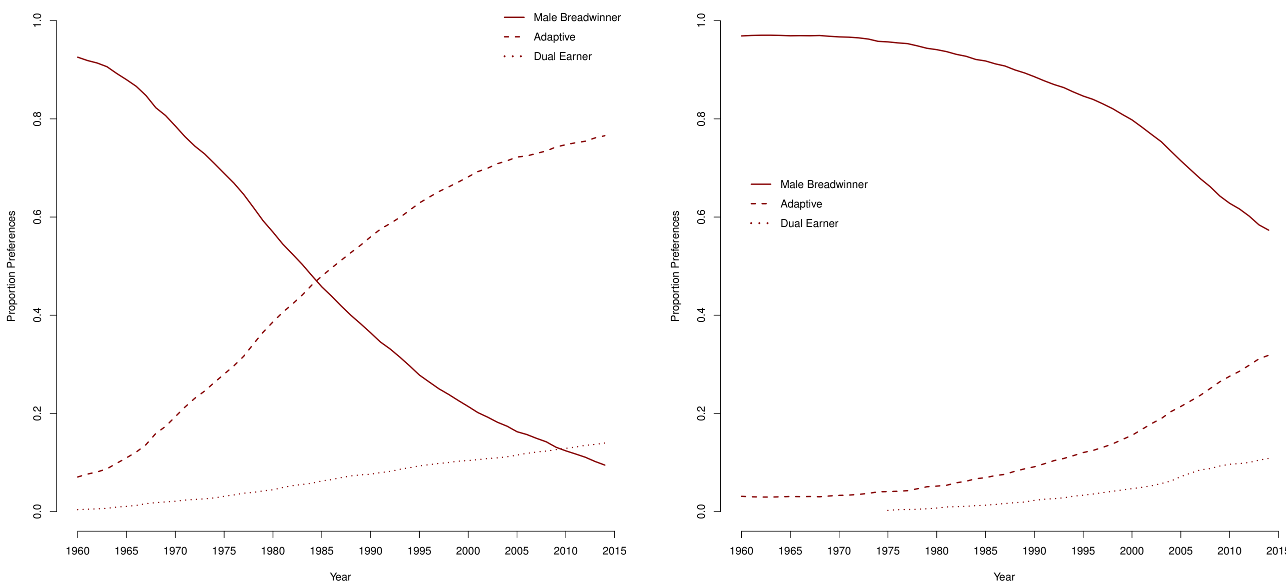
To obtain the *initial age structure* of the population we use the 1940 Spanish census. For the *initial distribution of the population by education*, we use information from the 1970 census, which is the first to present disaggregated population figures and from the 2011 census for the same distribution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

Given data limitations, the estimation of the probabilities related to *gender preferences* is not possible. Largely, we remain in the theoretical level, although there are some scattered data points which can aide in the calibration of these parameters. 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.

Considering this information we produce a plausible scenario presented in figure 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 causes an increase of the conflict within couples. An interesting possibility here is to create different scenarios with varying degrees of household-level gender conflict to test its impact on aggregate fertility trends.

Figure 5: Proportions of Women with a Given Preference, Ages 15-50 | 1960-2014, Spain.



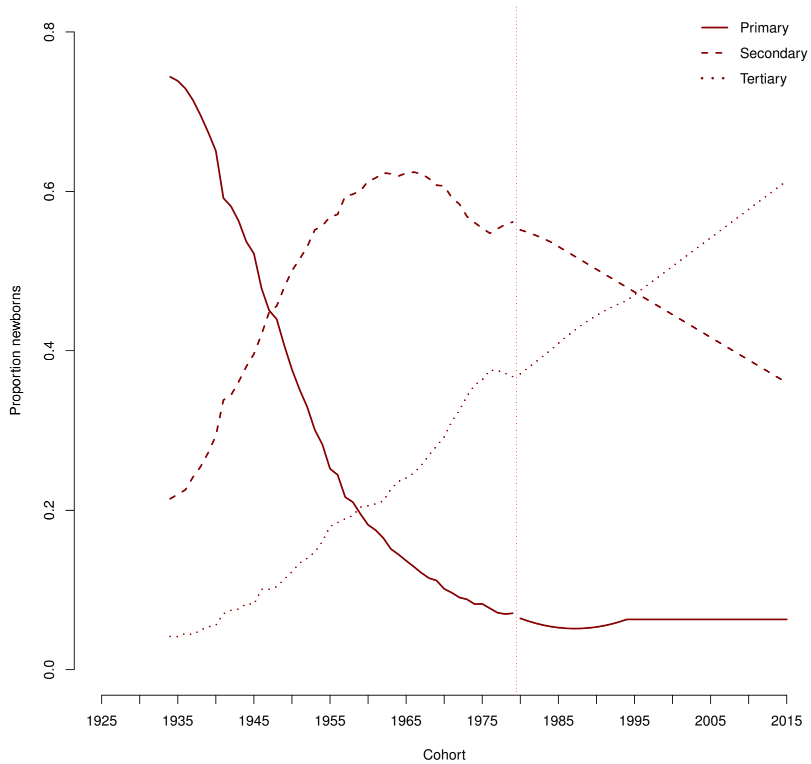
(a) Females

(b) Males

Information from the 2011 census is used to assign the newborns in our model the *education level* they will attain. Figure 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%).

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

Figure 6: Observed and Predicted Proportion of New Borns by Achieved Education level | Females, Spain.



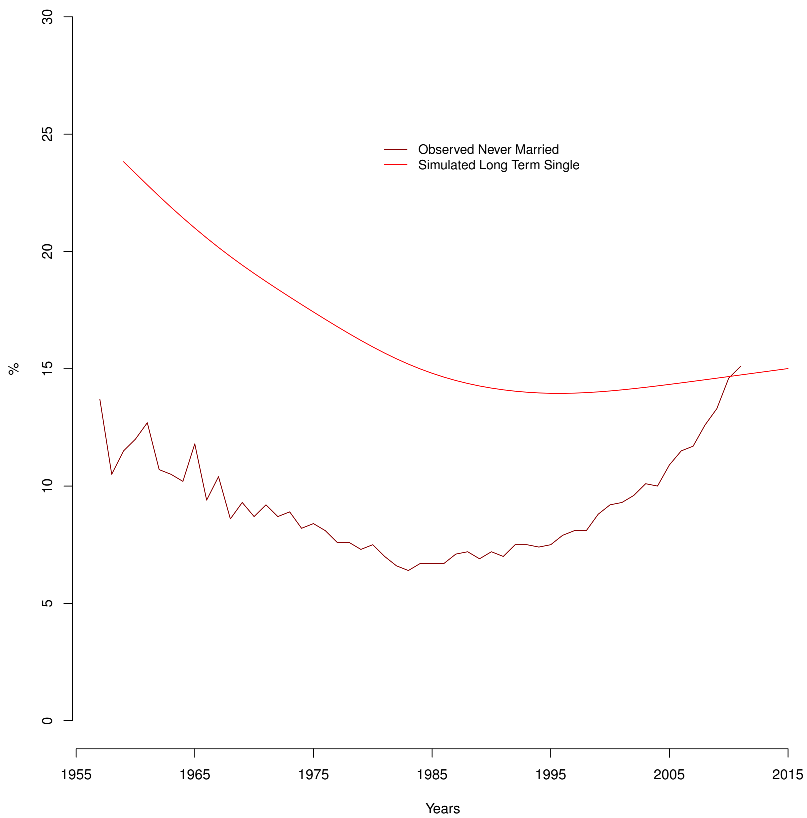
Source: 2011 Spanish Census, National Statistics Institute

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 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.

The main difficulty in the *union formation* dimension is that the available data refers to ages at marriage while our model consider all cohabitating unions, either formal or informal. This problem becomes relevant only from the 1990s onwards, when cohabitating unions in Spain start to represent a significant proportion of all unions, going from about 4% in 1995 to about 15% in 2005 (Creighton et al., 2013). Taken this figures into account we adjusted the parameters of the log-normal model to match the distribution of age at marriage until 1980 and slowly depart from then on, maintaining a higher level and a slight earlier pattern that the one exhibited by marriages.

Figure 7 shows the observed proportions of never married women at age 46 from 1960 to 2015. using this as a base we approximate the *proportion of women who spend most of their reproductive lives single*. Considering the above-mentioned figures regarding informal unions, we assume that the increase in the proportion never married since the 80s is a result of the rise in cohabitation, adjusting our approximation accordingly.

Figure 7: Observed and Simulated Proportions of Never Married Women at age 46 and Long Term Singles | 1960-2014, Spain.



Source: 2011 Spanish Census, National Statistics Institute

8 Results

In this section we initially present the fit of the model to a variety of aggregated observed outcomes and later the results of a series of exercises and scenarios created to test some of the hypothesis regarding the decline and recuperation of period fertility in Spain.

8.1 Model Fit

Figure 8 presents observed and simulated TFRs for our observation period. The model fits reasonably well considering the complex micro dynamics behind these aggregated trends.

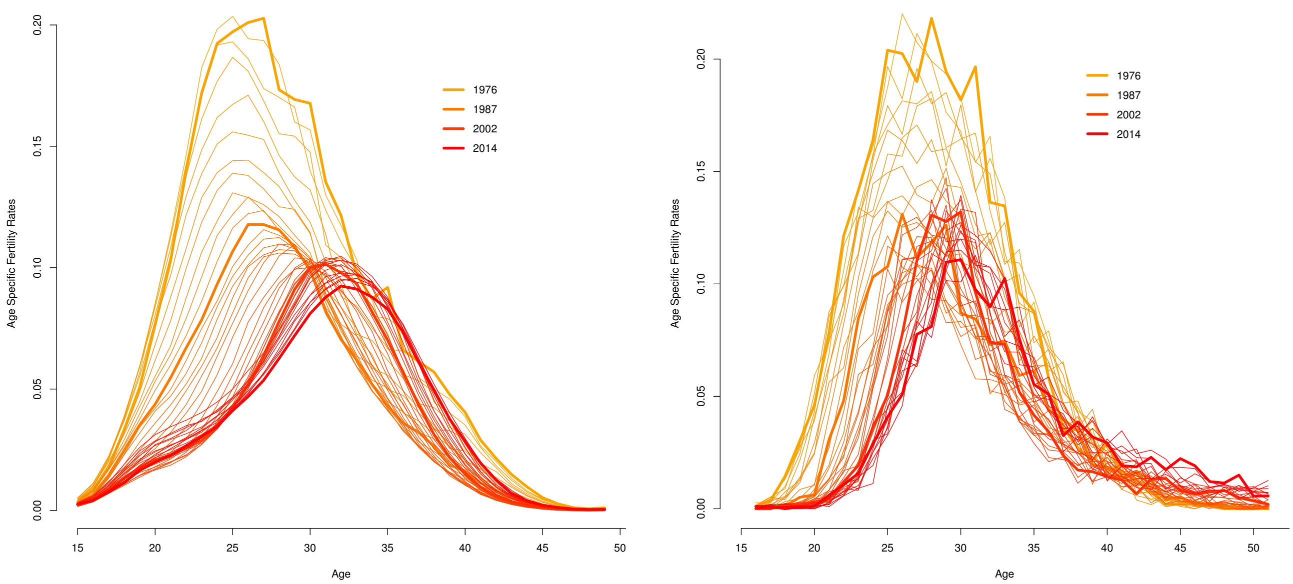
Figure 8: Observed and Simulated TFR | 1960-2014, Spain.

Source: 2011 Spanish Census, National Statistics Institute

The fact that the model can reproduce the trend described by the TFR does not necessarily mean the fertility trajectories in our simulated population are similar to those in our target population. For that reason we also explore how the model behaves with respect to other relevant outcomes.

Figure 9 shows observed and simulated age-specific schedules from the first to the last available data. Here the fit is also acceptable, specially 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 women with a markedly different pattern of childbearing. Since our model does not include migration, this pattern cannot be reproduced by our model. We obtain similar ages at different parities (see figure 10 for the mean age at first birth) by compensating with a simulated distribution with a peak slightly to the left of the observed one.

Figure 9: Observed and Simulated Age-Specific Fertility Rates | 1976-2014, Spain.

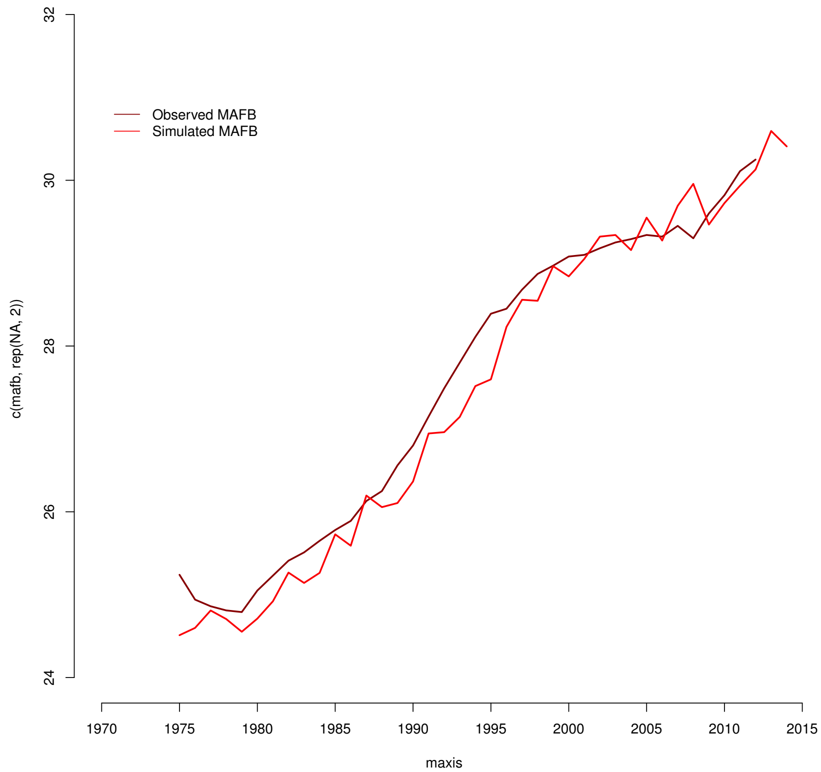


(a) Observed

(b) Simulated

Figure 10 shows the observed and simulated evolution of the mean age at first. As we will describe later, the pattern of rapid increase followed by a stabilization since the late 1990s is key to understand period fertility patterns. The sudden re-increase around 2008 is linked to the most recent economic recession.

Figure 10: Observed and Simulated Mean Age at First Birth | 1975-2014, Spain.



Source: 2011 Spanish Census, National Statistics Institute

Another outcome which conveys important information is the proportion of females which remain childless at the end of their reproductive lives. As shown in figure 11 the model correctly reproduces the observed trend. The relatively high levels at the beginning of the observation period are connected to higher levels of never married women, while the rise towards the end is explained both by higher proportions of females choosing to remain childless and others failing to achieve their reproductive goals.

Figure 11: Observed and Simulated Proportions of Childless Women at age 46 | 1975-2014, Spain.

Source: 2011 Spanish Census, National Statistics Institute

Finally, we present model outcomes with respect to the distribution of women with different family size ideals, a key dimension of our model. Sobotka and Beaujouan (2014) presents the longest available series regarding family size ideals for Spain. They show how the proportion of women with an ideal of three or more children falls from approximately .60 to .20 between 1981 and 2011 while the proportions with an ideal of two and an ideal of one increase from .38 to .68 and from .02 to .12 respectively.

Figure 12: Proportions of Women with Given Ideal Number of Children | Ages 15-50, Spain.

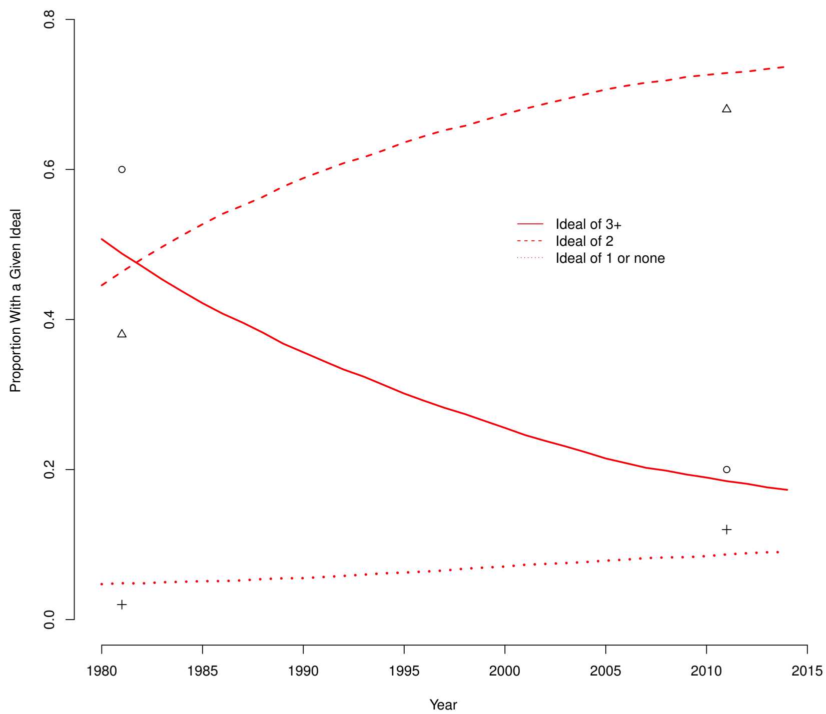
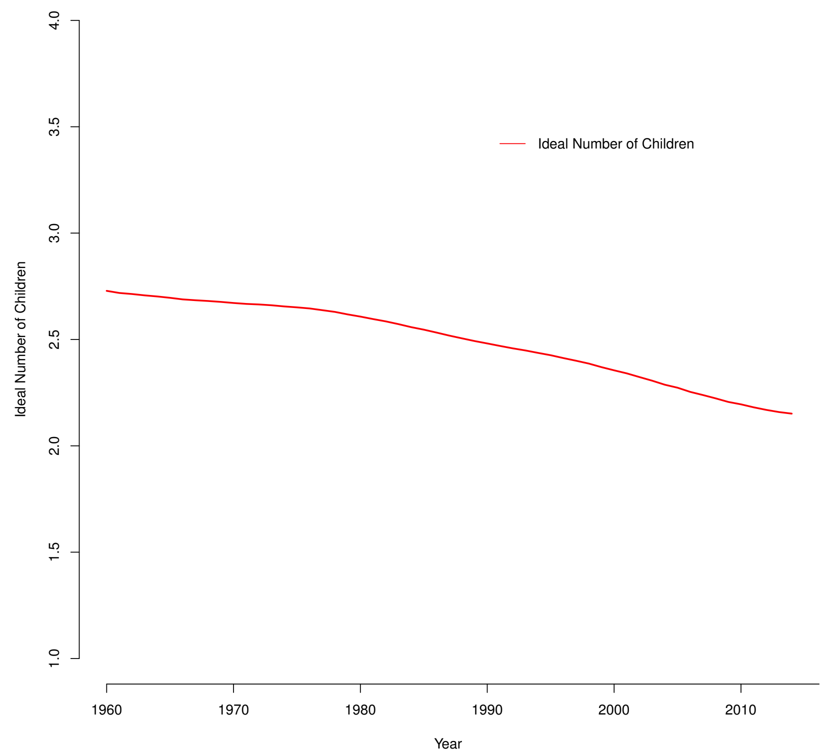


Figure 12 presents the proportions with given ideals produced by our model. These figures are close to the ones reported in Sobotka and Beaujouan (2014) (represented by points in the figure) and they show that, behind the apparent stability of family size ideals, there have been relevant compositional changes. In fact, in our simulated population the average family size ideal changes modestly during the observation period, remaining slightly above two children as shown in figure 13. This is an important fact to keep in mind, since as we will show later, this modest decline can result in significant change in period fertility.

Figure 13: Average Ideal Number of Children | Women, Ages 15-50, Spain.



Unintended pregnancies are not modeled explicitly, but included in the "ideal number of children" (for the sake of simplicity). This matters for the interpretation of trends in figure 13, as part of the decline is related to fertility control more than to a change in preferences. In any case, as we move forward in time this quantity increasingly represents an expression of true preferences.

8.2 Analysis: Scenarios

8.2.1 High Gender Equity

After having assessed the fit of the model to relevant aggregated outcomes, we present results from a series of scenarios with the aim of testing recent hypotheses regarding the decline and recuperation of fertility.

In order to test the role of gender dynamics we present results from a model 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 14). 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 gender equity does not play a relevant role in our model. 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 entered the "danger zone" of low fertility and would be nowadays part of that group of countries with brighter prospects with respect to the pace of population aging.

Another interesting result from this experiment is related to the absence of the marked effect of the economic recession in the last period, which can be observed both in the original model and the empirical tfr. We interpret this as an indication of a tipping point dynamic in which the effects of economic hardship are only visible when they act on top of other constraints.

Figure 14: Observed vs. Simulated TFR with High Gender Equity | 1960 - 2014, Spain.

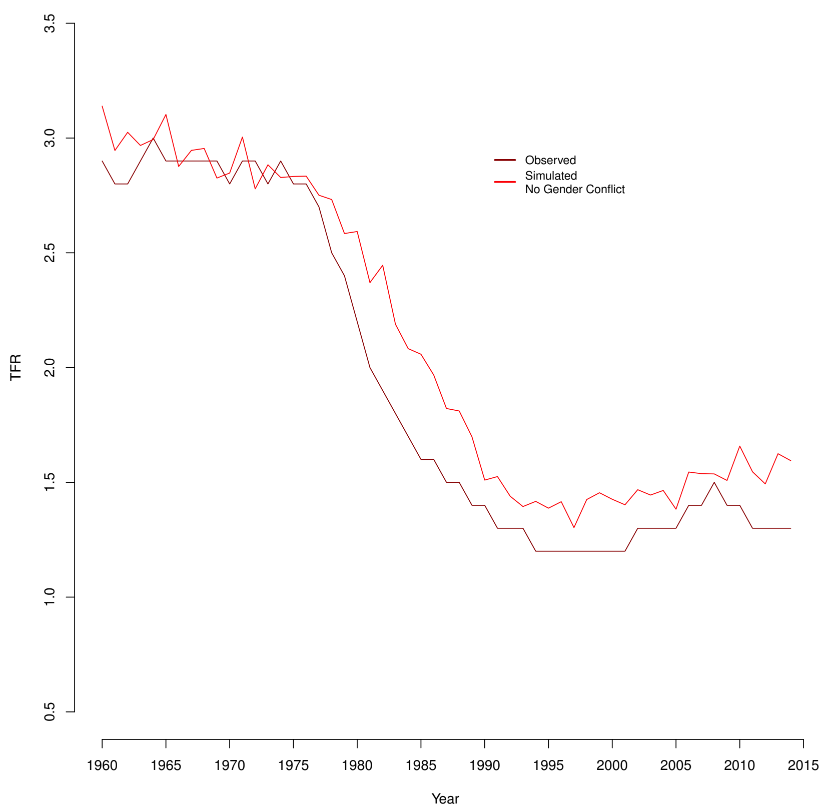
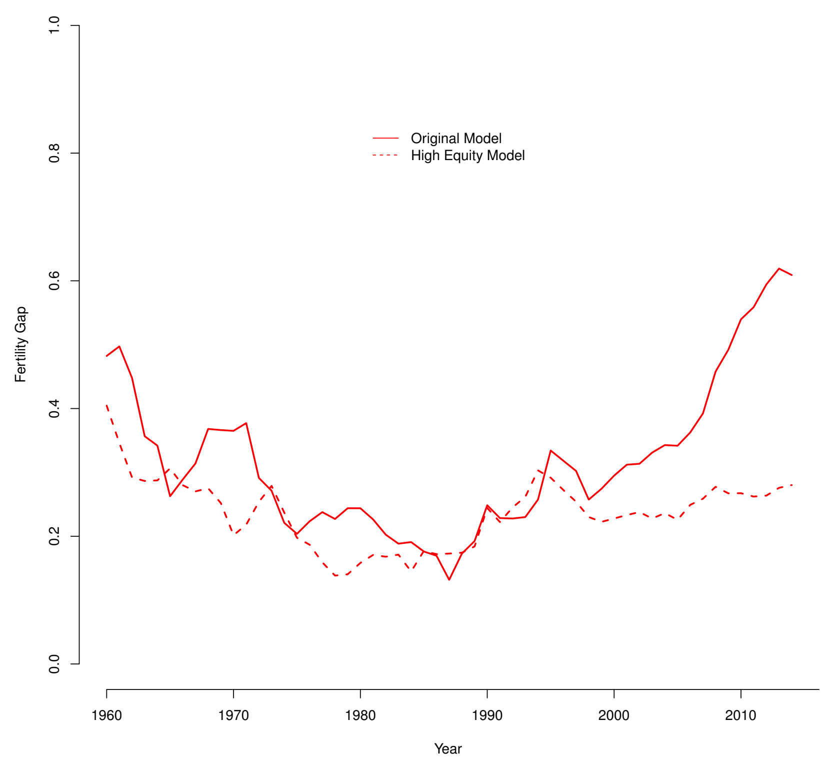


Figure 15 compares the fertility gap in the original vs the high gender equity scenario. The gap refers to the average distance between the ideal and the actual number of children for all female agents with an ideal of less than three children. Until the 1980s the gap in both models is similar and it is mostly explained by the proportion of females 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 agent's 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 that 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 males and female preferences regarding family/work balance.

Figure 15: Fertility Gap | 1960 - 2014, Spain.

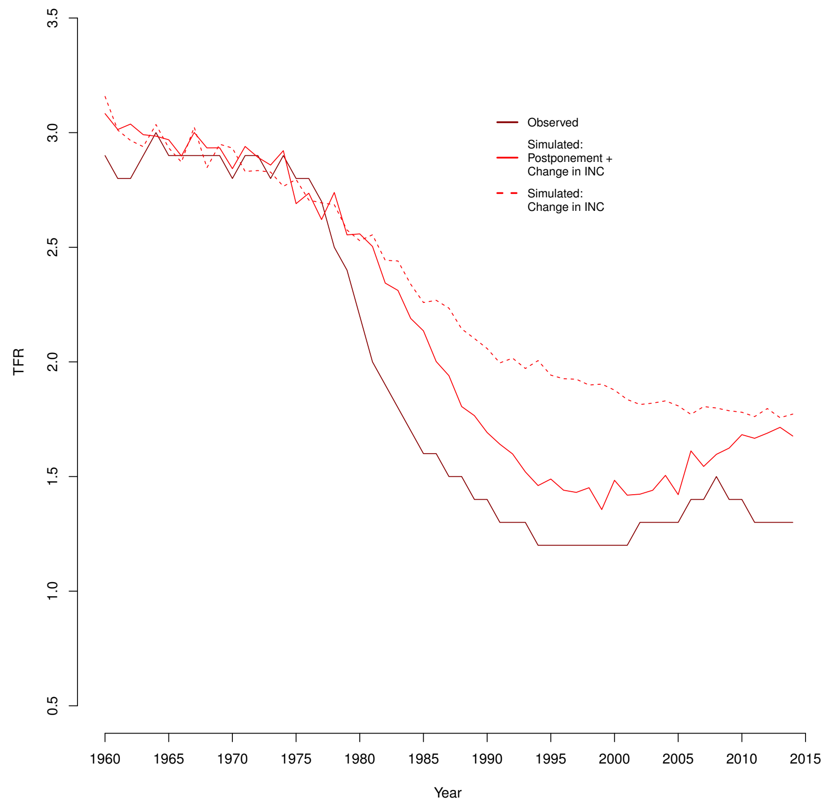


8.2.2 Compositional Changes + Postponement

Having explored the role of gender equity we now direct our focus to other relevant factors in the explanation of the shape of the observed period fertility trends. In figure 16 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 first of these effects 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. In other words, according to our model the steep period fertility decline is a direct consequence of the 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) is a direct consequence of the slowing down in 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 16). 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 16: 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 of two as shown in figure 13) is explained by the fact that we are still assuming a proportion of around .15 of the population that never marries. It is likely, however, that in a world without gender inequities and without economic uncertainty this proportion will be lower and the level of period fertility closer to replacement.

9 Conclusions

The use of an agent-based model of reproductive decision-making allowed us to gain some important insights regarding contemporary period fertility trends in Spain. One of the most interesting results refers to the role of family size preferences. Given the lack of historical data and the stability of contemporary trends, most previous research has overlooked the importance of preferences. We showed, however, how a distributional change in the numbers of women with different family size ideals can explain a significant part of the decline in period fertility in the second half of the twentieth century.

As shown by previous cohort approaches, postponement explains another significant part. In fact, we can conclude from our analysis that the observed collapse of period fertility was brought about when the cohorts of women who experienced radical improvements in educational attainment since the 1940s started replacing cohorts with more traditional preferences by the sixties and seventies.

According to our model, these two factors alone, postponement and compositional changes with respect to family size ideals, can explain the U-shape pattern of decline and recuperation of period fertility. While the conflict resulting from asymmetrical gender preferences and period effects connected to economic uncertainty explain the extent of these negative and positive trends.

One of our main goals was to test the hypothesis that connects fertility decline and recuperation with an increase and subsequent decrease in the conflict over the gendered division of labor within the household. As mentioned earlier, an 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" resulting from matching expectations. As we have said, however, the bulk of the decline results from a relative change in the number of women with different family size ideals, not from a significant change in the ideals themselves. Besides, those ideals remain above replacement throughout the process, therefore they can hardly be described as a trend towards "less family".

As we showed, 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.

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 conflict over the gendered distribution of paid and unpaid work is still key in our account. To the extent that it can potentially explain the difference between remaining or leaving the danger zone of period fertility rates below 1.5 children per women.

Nevertheless, in its current form, our model is better suited to obtain qualitative insights regarding the 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 introduce in our model in coming versions 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 we hope to have made a strong case for the usefulness of an agent-based computation approach for the analysis of long term fertility trends and the testing of competing theories. The agent-based approach forces us to adopt the perspective of individuals and therefore it provides a more direct behavioral foundation for fertility models.

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