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Research Material

Simulating family life courses: An application for Italy, Great Britain, Norway, and Sweden

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Abstract

BACKGROUND

Family patterns in Western countries have changed substantially across birth cohorts. The spread of unmarried cohabitation, the decline and postponement of marriage and fertility, and the rise in nonmarital births, partnership instability, and repartnering lead to an increasing diversity in family life courses.

OBJECTIVE

In this paper we demonstrate how to set up a tool to explore family life trajectories. This tool models the changing family patterns, taking into account the complex inter-relationships between childbearing and partnership processes.

METHODS

We build a microsimulation model parameterised using retrospective partnership and childbearing data. The data cover women born since 1940 in Italy, Great Britain, and two Scandinavian countries (Norway and Sweden), three significantly different cultural and institutional contexts of partnering and childbearing in Europe.

RESULTS

We guide readers through the modelling of individual life events to obtain a set of aggregate estimates, providing information on the power, technical structure, and underlying assumptions of microsimulations. Validation of the simulated family life

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courses against their real-world equivalents shows that the simulations not only closely replicate observed childbearing and partnership processes, but also provide high quality predictions when compared to more recent fertility indicators.

CONCLUSIONS
Using observed population estimates to systematically validate the results both validates our model and increases confidence that microsimulations satisfactorily replicate the behaviour of the original population.

CONTRIBUTION
We create and validate a microsimulation model that can be used not only to explore mechanisms throughout the family life course but also to set up scenarios and predict future family patterns.

1. Introduction

The family and the associated family demography research witnessed major changes in the second half of the 20th century (Jokinen and Kuronen 2011; Seltzer 2019). Family patterns in Western countries underwent deep transformations in that period, with a rapid decline in fertility rates below replacement, postponement of marriage and parenthood, increases in cohabitation and nonmarital childbearing, and declining stability of couple relationships, even with children (Sobotka and Toulemon 2008; OECD 2011; Oláh 2015). As a result, a wide variety of family forms emerged other than the married nuclear family, e.g., sole-parent families, reconstituted families, and unmarried couples with or without children (Jokinen and Kuronen 2011). This increasing family diversity represented a destandardisation of the family life course (Brückner and Mayer 2005; Thomson, Winkler-Dworak, and Kennedy 2013) and, consequently, a spread of alternative pathways to family formation and childbearing (Fürnkranz-Prskawetz et al. 2003; Smock and Greenland 2010; Guzzo 2014).

At the same time, the emphasis in the scientific study of family demography changed from aggregate-level (macro) analysis to research on individual (micro) behaviour, and from studies on demographic structures to studies on processes underlying family life events (Willekens 1999, 2001; Billari 2006). Particularly, life course research studies individual-level demographic trajectories, constituting a series of transitions over long stretches of a lifetime (Mayer 2009; Elder, Johnson, and Crosnoe 2003). Trajectories are regarded as the outcome of individual characteristics in a given cultural or institutional context (ibid). However, many micro-level studies only focus on selected transitions or on specific situations and thus provide only a fragmented picture of contemporary fertility and family dynamics (Matysiak and Vignoli 2008). Furthermore, there has only been a limited effort to draw conclusions from micro-level studies to explain macro-level outcomes (ibid). In fact, the life course approach does not explicitly provide a transformational mechanism for the micro–macro link (Billari 2006).

The aim of this paper is to demonstrate how microsimulation can be used to link micro-level relationships to macro-level outcomes in family life course research. Family structure is an outcome of interacting childbearing and partnership processes, and microsimulation can be considered as a major tool that links multiple processes to generate complex dynamics (Willekens 1999, 2001) while preserving logical rigor (Burch 2018). Our approach explicitly takes into account the interrelationship between individual childbearing and partnership dynamics, offering important insights into how the individual heterogeneity in family transitions reinforces or offsets over the life course. We set up a simulation model of the family life course and derive by aggregation (simulated) family structure indicators at the population level. By doing so, we not only explicate the various steps in modelling, simulation, and validation but also provide revealing information on the power, technical structure, and underlying assumptions of microsimulations. We parameterise the microsimulation model using survey data from Italy, Great Britain, and two Scandinavian countries (Norway and Sweden) – three European settings with significantly different cultural and institutional partnering and childbearing contexts. We emphasize the capabilities of the microsimulation model by giving examples of research questions it can help to answer. For instance, the present microsimulation model has been employed very recently to investigate the contribution of the rise in cohabiting parenthood to family instability (Thomson, Winkler-Dworak, and Beaujouan 2019).

The remainder of the paper is organized as follows. Section 2 reviews the method of dynamic microsimulation and briefly depicts simulation models in family demography. Sections 3 to 5 outline the architecture of the microsimulation model, provide details on the data and on the estimation of the simulation parameters, and validate the results against their real-world equivalents. Finally, in section 6 we discuss the contribution to family research, limitations, and potential research questions that could be answered by using this microsimulation model.

2. A review of dynamic microsimulation

2.1 General

Dynamic microsimulation dates back to Guy Orcutt’s (1957) seminal paper, in which, frustrated by the shortcomings of macroeconomic modelling at the time, he proposed a new model of socioeconomic systems. The central idea was that processes are modelled at the individual/micro level and that predictions at the macro level are obtained by aggregation. Furthermore, the behaviour of each simulated individual in each time period is the result of stochastic experiments, typically using Monte Carlo methods. The associated probabilities, usually derived from empirical evidence, are dependent on conditions or events prior to the behaviour and thus vary over time as the system develops or external conditions change (ibid; Spielauer 2011; Zagheni 2015).

Microsimulation is a tool for generating synthetic micro-unit-based data, which can then be aggregated to generate indicators at the population level. In contrast to other micro–macro transformational mechanisms, the aggregation does not require any assumptions at the micro level that one would not like to impose – homogeneity, lack of interaction, etc. (Billari 2006).

Besides the micro–macro link, microsimulation can also be used to answer many ‘what-if’ questions that otherwise cannot be answered (Li and O’Donoghue 2013). Specifically, simulation allows for quantifying the contribution of a given process to the complex pattern of change (ibid), which is not necessarily easy to infer from single-event model estimates in the presence of many covariates and feedback processes (Aassve et al. 2006).

In addition to its explanatory power, microsimulation serves predictive purposes, i.e., the projection of future life courses, including the mere completion of the family life courses of cohorts who are still of reproductive age, and more complex implementation of scenarios based on distinct assumptions of various parameters (e.g., policy simulations), raising awareness of current and future trends (Spielauer 2011). Furthermore, empirical validation of the simulation results allows for assessing the statistical models currently in use in family demography (Aassve et al. 2006).

In sum, microsimulation adds synthesis to analysis (Willekens 1999, 2001; Spielauer 2011), and thus may help to explain complex dynamics. However, the microsimulation approach is not without limitations: Simulation and particularly the parametrisation are computer-intensive and data requirements regarding quality and sample size are hard to meet. A methodological limitation relates to the degree of model detail. Although failure to model correlation between events may lead to less variation in key output variables (Ruggles 1993), model complexity does not go hand in hand with prediction power due to the stochastic nature of microsimulations (van Imhoff and Post 1998). The greater the number of processes modelled, the higher the number of Monte Carlo experiments involved during the simulation. In addition, randomness might increase with the number of variables included in the simulation model, as parameters are typically based on statistical inference from empirical data, potentially subject to sampling errors if limited in size.

Another shortcoming of classic microsimulation is the lack of interaction and feedback between individuals. Agent-based models, by contrast, integrate micro-based behavioural theories while allowing individual agents to interact and adapt through time, with macro-level outcomes. Nonetheless, these models do not serve the same purpose: while microsimulation predicts aggregate behaviour, in agent-based modelling the main emphasis is placed on explaining it (for applications in demography, see e.g., Billari and Prskawetz 2003; Billari et al. 2006; Grow and Van Bavel 2016).

2.2 Microsimulation of family dynamics

Since the beginning of microsimulation, dozens of large-scale general-purpose models and countless smaller models have been developed around the world.[5] In family science, applications range from modelling family and kinship networks (e.g., Wachter 1997; Tomassini and Wolf 2000; Murphy 2004, 2011; Zagheni 2011) and human reproduction and fecundity (Ridley and Sheps 1966) to contraceptive behaviour (Thomas et al. 2017). Currently, only a few microsimulations focus on family-building issues, including FAMSIM (Lutz 1997; Spielauer and Vencatasawmy 2001) for the evaluation of family policies, an extension of the MicMac model to mate-matching and couple dynamics (Zinn 2011, 2012, 2017), and several applications of RiskPaths (Spielauer 2009a, 2009b) on the interaction of fertility and union processes (Spielauer, Kostova, and Koytcheva 2007; Bélanger, Morency, and Spielauer 2010; Thomson et al. 2012; Spielauer and Dupriez 2017).

In particular, of the latter, two studies are most relevant to our goals. Bélanger, Morency, and Spielauer (2010) investigate differences in partnership behaviour with respect to legal status (marriage vs. common law) and stability for fertility in Quebec as opposed to the rest of Canada. Similarly, Thomson et al. (2012) study the implications of changes in union formation and dissolution for fertility in France. They model the reciprocal relationships between partnership and birth history in much greater detail than Bélanger, Morency, and Spielauer (2010), incorporating not only current parity or partnership status but also detailed combinations of current and past union status at birth. However, Thomson et al. (2012) consider all partnerships together, ignoring differences between marital and nonmarital unions for childbearing timing and partnership stability. While the latter assumption might be justified for France (Toulemon and Testa 2005), it is clearly not tenable in different institutional contexts.

[5] A detailed description of most prominent microsimulation models can be found in, for instance, Zaidi and Rake (2001), Morand et al. (2010), and Li and O'Donoghue (2013) and their applications in, e.g., Harding and Gupta (2007) and Zaidi, Harding, and Williamson (2009).

2.3 Foundations of our microsimulation model

In this paper we develop a microsimulation model that aims to extend our understanding of the link between union dynamics and fertility and how it changes across cohorts. Our goal is to set up a model that allows us to study the implications of the reciprocal relationships between birth and union processes for family outcomes and to identify important mechanisms behind the change in family life courses. In fact, the microsimulation – as a synthesis of single models – can be seen as the engine of family life trajectories (Thomson et al. 2012; Thomson, Winkler-Dworak, and Beaujouan 2019) that metabolizes complex, reciprocal relationships between union and birth histories. The models not only incorporate direct associations between parity and marital/partnership status, but also implicitly consider the more complex associations between cohabiting parenthood, partnership stability, repartnering, and prior childbearing.

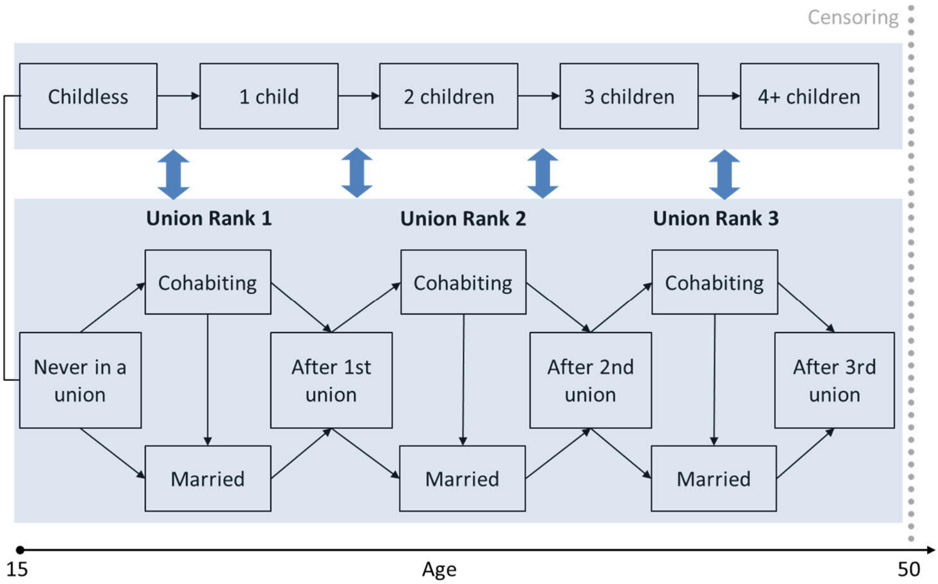
To illustrate the mechanisms of the engine, we take as an example the complex theoretical link between prevalence of cohabitation and childbearing levels as anticipated in the literature (see also section 3.1). On the one hand, the spread of cohabitation may depress aggregate fertility levels. Indeed, cohabitation generally tends to postpone marriage and childbearing, and a higher age at first birth is usually associated with a lower ultimate number of children. On the other hand, if childbearing is also taking place within cohabitation, cohabitation may enhance fertility levels due to the relative youthfulness of cohabiters in comparison to married couples. However, the latter effect not only depends on age and fertility differentials between cohabiting and married couples, but also on differences in stability between cohabiting and married unions and on the net impact of union instability on fertility, which all, again, hinge on age and parity. Hence, an increasing prevalence of cohabitation not only directly affects aggregate fertility levels but also operates via couples' age and union stability, where all components of the family life course are intermeshed like cogwheels in a machine. Each component of the engine is influenced by prior experiences and fixed characteristics and, conversely, will have consequences for later family events. The set of all specific life courses generated by that engine constitutes the simulated population (Thomson, Winkler-Dworak, and Beaujouan 2019).

3. The model

We develop a dynamic, continuous-time, single-sex (women only),[6] competing risk microsimulation model, comparable to that employed by Thomson et al. (2012), but additionally differentiating between marriage and unmarried cohabitation as in Bélanger, Morency, and Spielauer (2010). The state-space representation of the model is sketched in Figure 1. All women are assumed to be childless and never in a union at age 15. For birth processes we consider the transitions up to parity 4, while we model transitions into and out of marital/nonmarital partnerships up to union rank 3. We censor all observations from age 50 onwards. As indicated by the bidirectional arrows between the birth and union blocks, we also model the interrelationships of parenthood and partnership processes as theorised in section 3.1. Hence, we define – assuming conditional independence of the processes (Blossfeld and Rohwer 2002) – all transitions between birth and union states to be dependent on duration, age of the individual, birth cohort, and detailed combinations of current and past unions and births. The results for the simulated family life trajectories can thus be "interpreted as cohort life table indicators coming from a fairly large age-, duration- and rank-specific multi-state life table" (cf. Bélanger, Morency, and Spielauer 2010: 354). Note that these models, which will then underlie the simulation, are based purely on demographic events.

[6] The microsimulation model can be used to simulate male family life courses as well, provided data on childbearing and partnership histories of sufficient quality are available to parameterize the microsimulation model. In this paper we focus on female birth cohorts due to the limited availability of comparable national data for men to assess the validity of the simulations.

Figure 1: State-space representation of the model



Note: All transitions depend on duration, age of individual, birth cohort, and detailed combinations of current and past unions and births (marital status, number of children, shared/nonshared with current partner, and age of youngest child)

3.1 Modelling the transition rates

We model the transition rates based on theoretical reasoning on the interrelationships between childbearing and partnership processes;[7] a brief review and its empirical evidence can be found below (for a more detailed discussion of the modelling of the childbearing and partnership processes, see Winkler-Dworak et al. 2019).

[7] The reciprocal relationships between the partnership and childbearing processes suggest that births and unions are endogenous to each other. Studies addressing the potential endogeneity either focus only on selected processes at the intersection of childbearing and partnerships, or compromise in the modelling of the processes due to the complex nature of the statistical model. By contrast, here we strengthen the modelling of the complex interaction between partnering and childbearing, while leaving the incorporation of correlated unobserved heterogeneity between processes for further research.

3.1.1 Childbearing contingent on partnership trajectories

Childbearing and marriage have become increasingly disconnected since the middle of the 20th century, though the vast majority of children in European countries are born to mothers and fathers coresiding in either an unmarried cohabitation or in a marriage (Kiernan 2001; Perelli-Harris et al. 2012). Nonetheless, marriage remains particularly valued for childbearing: married couples have both higher fertility intentions and higher fertility rates than unmarried cohabiting couples (Baizán, Aassve, and Billari 2003, 2004; Steele et al. 2005; Spéder and Kapitány 2009). The difference may be driven by social or legal norms, preference for childbearing within marriage, or lower commitment in cohabitations (ibid; for legal differences between cohabitation and marriage related to childbearing see, e.g., Perelli-Harris and Sánchez Gassen 2012).

The end of a union, either by separation or death of the partner, supposedly reduces birth risks, at least temporarily, but at the same time produces a pool of persons who may enter new partnerships. New unions represent new opportunities for childbearing both for childless couples – an increasing share of first children is born in second or subsequent unions (e.g., Beaujouan 2011) – and for couples in which one or both partners already have children (Guzzo 2017). Having children seems to symbolise a couple's commitment to each other and their status as a family unit (Griffith, Koo, and Suchindran 1985), and can also be an opportunity to give siblings of close age to children of a previous union (Guzzo 2017). In fact, several studies show that birth risks are elevated if the prospective child is the first or second shared birth in the union (Thomson et al. 2002; Thomson 2004; Vikat, Thomson, and Hoem 1999).

Building on the theoretical arguments above, we model fertility rates to vary with individuals' age and duration since previous birth (i.e., age of the youngest child), partnership status, and order of the prospective child across and within partnerships. In particular, we precisely account for whether the previous children are from the current or a previous union.

3.1.2 Partnership formation contingent on current and past births

Conversely, the propensity to enter a partnership varies with pregnancy and presence of children. Pregnant, single women may seek to enter a union because of a desire to offer their child the social and economic protection of a partnership or because of normative pressure to legitimize the birth (Baizán, Aassve, and Billari 2003, 2004). After the delivery, mothers may prioritize their relationship with their children as opposed to seeking a (new) partner (Lampard and Peggs 1999), although the elevated risk of union formation during pregnancy seems to extend into the first year after the birth and drop sharply below pre-pregnancy levels thereafter (e.g., Baizán, Aassve, and Billari 2003, 2004). In addition, the presence of children may decrease partner attractiveness, and partner search costs rise with the number of children due to time constraints or fewer resources (Keeley 1977, cited in Baizán, Aassve, and Billari 2003, 2004; Bumpass, Sweet, and Castro Martin 1990; Ermisch, Jenkins, and Wright 1990). Overall, partnering is found to be less common among mothers (e.g., Brien, Lillard, and Waite 1999; Baizán, Aassve, and Billari 2003, 2004; Steele et al. 2005; Steele, Kallis, and Joshi 2006; for repartnering see Beaujouan 2012; Ivanova, Kalmijn, and Uunk 2013; Skew, Evans, and Gray 2009; Wu and Schimmele 2005).

In cohabiting couples, pregnancy may trigger marriage to strengthen the couples' commitment, to reinforce social and economic protection, to comply with social expectations and norms, and to safeguard children's rights (Baizán, Aassve, and Billari 2003, 2004; Kiernan 2001; Steele et al. 2005; Thorsen 2019). With the rise in social acceptance of childrearing within cohabitation and the changing meaning of marriage (Holland 2013), nowadays marriage often takes place after the birth (Thorsen 2019). Nonetheless, there is still ample empirical evidence that pregnant women strongly accelerate entry into both cohabitation and marriage, the latter for both single and cohabiting women (Brien, Lillard, and Waite 1999; Baizán, Aassve, and Billari 2003, 2004; Steele et al. 2005, 2006; Steele, Kallis, and Joshi 2006).

Hence, we model union formation rates and marriage rates depending on individual's age, duration since end of previous union for single women or union duration for cohabiting women, pregnancy, and the presence and age of the children.

3.1.3 Partnership separation contingent on current and past births

Children represent a large common investment in a partnership and their presence increases the cost of separation (Becker, Landes, and Michael 1977). Separation costs are assumed to be highest when the children are young or first-born (Lillard and Waite 1993; Steele et al. 2005), and couples with a further birth only face a small marginal increase in the cost of a potential separation (Lillard and Waite 1993). In fact, empirical studies have found support for the stabilizing effect of children on their parents' partnership, especially when young (see, e.g., Steele et al. 2005), but evidence is mixed regarding the effect of different birth orders (Lyngstad and Jalovaara 2010).

The effect of children from previous relationships on partnership stability is less straightforward. On the one hand, having children, regardless of their parentage, might constitute a shared interest and thus reduce dissolution risks (Steele et al. 2005). On the other hand, stepchildren might be perceived as a potential source of conflict and hence increase partnership instability. Empirical evidence shows that unions are generally less stable when there are stepchildren (Lyngstad and Jalovaara 2010; Beaujouan 2016).

The stability of partnerships differs by union type, and cohabitation is perceived as less stable than marriage. Specifically, premarital cohabitation has long been associated with higher divorce rates (Brines and Joyner 1999; Liefbroer and Dourleijn 2006; Hewitt and De Vaus 2009; Reinhold 2010). The difference in stability has been attributed to several effects: selection, i.e., individuals with a high propensity to union dissolution marry less often (Lillard, Brien, and Waite 1995; Steele et al. 2005); a general stabilising role of the institution of marriage (Brines and Joyner 1999); and differences in age at coresidence – cohabitation taking place earlier and hence being more exposed to separation (Kuperberg 2014). However, with the spread of marriage-like cohabitation, the greater instability of unmarried couples appears to lessen (Liefbroer and Dourleijn 2006; Hewitt and De Vaus 2009; Reinhold 2010; Manning and Cohen 2012), while at the same time seeming to select the most stable unions into marriage (Liefbroer and Dourleijn 2006).

To sum up, we model partnership separation rates – similar to union formation rates – depending on individual's age, union or marriage duration, pregnancy, and presence and age of children. In addition, we model them to vary by partnership history, i.e., whether the present children were born in or before the current union, and, specifically for divorce rates, whether the marriage was preceded by a phase of nonmarital cohabitation.

3.2 Simulation

The simulation model is implemented in Modgen, a generic microsimulation programming language developed and maintained at Statistics Canada (2009). The model is an expanded variant of the RiskPath model (Spielauer 2009a,b),[8] which has also been the building block for Thomson et al. (2012) and Bélanger, Morency, and Spielauer (2010). Details of the microsimulation technique are provided in Appendix A.

The parameters for the simulation are produced from proportional hazard regressions using retrospective union and birth histories collected in several European surveys. Thus, simulations of events at later ages depend on the parameters observed only for older cohorts conditional on the same birth and union history and age group. This holds particularly for the most recent cohort born in 1980+, where we had to postulate the same cohort-specific rates as in the 1970–1979 cohort for most of the birth and union processes. The hypothesis that transition rates for the last cohorts remain constant does

[8] RiskPaths is part of the Statistics Canada collection of sample applications; the model and its code are available for download at https://www.statcan.gc.ca/eng/microsimulation/modgen/download/.

not take into consideration the possible shifts in later transitions, which have not yet been observed, when earlier transitions would have taken place with different timing than in earlier cohorts. Thus, we only present the microsimulation of the first four birth cohorts (i.e., for women born from 1940 to 1979) and subsequently discuss hypothetical life courses for women born in the 1980s to mid-1990s.

In order to gauge the validity of our simulated family life courses, we estimate the accuracy of the simulation output in each birth cohort by comparing the distribution of women by age, parity, and partnership status to their real-world equivalents. The latter are taken from the observed survey data and, if available, from each country's national statistics.

4. Parametrisation

We estimate our microsimulation model for different country settings representing three different cultural, institutional, and legal childbearing and partnership contexts, namely Italy, Great Britain, and two Scandinavian countries (Kiernan 2001; Coleman 2013). While partnerships and childbearing in Italy usually follow traditional patterns, an increase in cohabitation, out-of-wedlock births, and divorce has been observed since the early 2000s (Rosina and Fraboni 2004; Di Giulio and Rosina 2007; Vignoli and Ferro 2009; Gabrielli and Hoem 2010; Meggiolaro and Ongaro 2010; Gabrielli and Vignoli 2013). In Great Britain, by contrast, fertility outside marriage is socially accepted and union dissolution has become a common experience, especially for cohorts born after 1960 (Basten, Sobotka, and Zeman 2014). Finally, Norway and Sweden were among the first countries to already see an early and fast rise in divorce rates, unmarried cohabitation, and births out of wedlock in the 1960s (Sobotka and Toulemon 2008). A large difference between the United Kingdom and Norway, for instance, is that in 2000–2004, 30% of first births were occuring within cohabitation in the UK as against 54% in Norway (Perelli-Harris et al. 2010b).

4.1 Data

The Italian data stems from the multi-purpose household surveys on Family and Social Subjects carried out by the Italian National Statistical Institute (ISTAT) in 2003 and 2009. The 2003 version has been harmonised by the participants in the Nonmarital Childbearing Network (Perelli-Harris et al. 2010a, see www.nonmarital.org). In our study we keep only women born from 1940 onward, excluding those who had a first child or entered a first partnership before the age of 15 or after the age of 49, or were born abroad, leaving 30,255 women in our sample.

Estimations for Great Britain are based on 10 yearly datasets (2000–2009) from the Centre for Population Change GHS database 1979–2009 (see Beaujouan et al. 2014 for details) and on the first wave of the Understanding Society Survey (2009–2011). After excluding unusable partnership histories (about 2% of the respondents), the partnership histories are deemed as valid in GHS (Berrington et al. 2011) and the partnership histories of Understanding Society closely match those of the GHS (authors' verification). The birth histories in the GHS have been revised because they underestimated total births reported, and new weights were constructed for the full series (Ní Bhrolcháin, Beaujouan, and Murphy 2011; Beaujouan, Brown, and Ní Bhrolcháin 2011). The remaining small bias in a few recent birth cohorts is outweighed thanks to the very large number of observations in these cohorts in the Understanding Society Survey, and in our final sample completed fertility levels closely match the numbers from vital statistics. The final sample consists of 61,718 women born in Great Britain in 1940 or later, having their first child and entering a partnership, if at all, after age 15, as for Italy.

For the data representing Scandinavia, we combined harmonized versions of the nationally representative 2007/2008 Norwegian and 2012/13 Swedish GGSs. Again, we use the harmonised version from the Nonmarital Childbearing Network (Perelli-Harris et al. 2010a). Validation of GGS-based cohort indicators shows that the latter provide an accurate account of demographic trends in Norway for cohorts born since the mid-1940s (Vergauwen et al. 2015). Cohort indicators from Swedish administrative registers were used to validate a number of parameters in the simulated population. Each survey had a smaller sample than for Italy or Great Britain; by combining the samples we were able to make distinctions in union and birth histories that would not have been possible with the separate samples. Differences have been observed between the two countries' birth and union behaviours (e.g., Andersson, Thomson, and Dunatava 2017), but they are much smaller than with respect to the other countries. We applied the same selection criteria as in Italy and Great Britain, producing an analytic sample of 6,589 Norwegian-born women and 4,446 Swedish-born women, a total of 11,035 women.

4.2 Hazard regression of transition rates

For the hazard regression of progression to each birth order and to the formation and dissolution of union for first and second unions we use piecewise constant exponential models, as postulated in the RiskPath model. Birth transitions are timed at conception, which is assumed to occur nine months prior to a reported birth, whereas the end of the marital union is timed at the reported date of separation rather than the legal date of divorce in order to avoid overlapping partnership histories. Union and marriage formation are treated as competing risks by employing stratified models with transition-specific covariates, as women out of a partnership can choose either to marry or to enter an unmarried cohabitation. In the same way, marriage and separation of a cohabiting union are treated as competing risks. The covariates for all transitions include age, birth cohort, and detailed combinations of past unions and births.

The baseline duration is measured by the age of the women for the conception of the first live birth, or, more specifically, by the time since the 15th birthday for forming a first union irrespective of the type of the union. For higher order events, the baseline clock is measured by the duration since the preceding birth or union event.

To account for cohort differences in the timing of the events, we include a duration–cohort interaction using stepwise linear duration splines. The competing risk processes were estimated using stratified models with transition-specific covariates. As outlined above, observations are censored by the respondent's 50th birthday or by the date of survey, whichever occurs first. Model selection is based on the AIC statistics. All models were estimated by maximum likelihood as implemented by STATA 13 (StataCorp 2013). The full set of estimated model coefficients can be found in Tables A-1–A-11 in Appendix B.

The following paragraphs summarize the main findings of the hazard regressions. They are overall in line with earlier observations on the associations between parenthood and partnering in Italy, Great Britain, Norway, and Sweden. An in-depth discussion of the results of the models can be found in Appendix B.

4.2.1 Childbearing processes

As expected, we find evidence of the postponement of maternity across cohorts in all countries, with first-birth rates showing major reductions at (very) young ages for Italy and the two Scandinavian countries, but less so in Great Britain, which is still characterized by teenage pregnancies in these cohorts, and rising first-birth rates at later ages in all countries. Similarly, risks of second and higher-order births have significantly increased for age 30 and above in all countries.

Married women continue to show higher birth rates than cohabiting women and much higher birth rates than women out of union, although the timing of parenthood and partnership formation has become less and less connected. Moreover, birth rates in second or third unions are higher than in first unions, for both childless women and couples with children from previous relationships, if the prospective child is the first or second birth in the partnership.

4.2.2 Partnership formation and dissolution processes

In line with previous research, in all countries, albeit at a different pace, the results show an increasing diffusion of cohabitation and union separations in the younger cohorts, a constant retreat from direct marriage and a postponement of marriage towards older ages, and a weakening link between marriage and childbearing. Except for Italy, women marry less and less when pregnant, but rather enter cohabitation. Union formation risks are still elevated shortly after birth, but mostly decline with increasing age of the children.

While children in a partnership are associated with lower separation risks, children born before the current partnership tend to inflate dissolution risks. The presence of children, except during pregnancy, inhibits repartnering. Likewise, children depress the risk of marriage within cohabitation, except when they are very young or born in the current partnership in Scandinavian countries.

Lastly, partnership history also influences marriage stability, as first marriages preceded by a premarital cohabitation are more unstable than direct marriages. Strikingly, for higher-order unions, the estimated effect is the opposite.

5. Results

The estimated parameters described in section 4 are fed into the microsimulation model, which generates 1 million hypothetical life courses of childbearing and union events for each cohort and each country setting. We aim to evaluate how close the simulated family life courses resemble their respective real-world equivalents in the three country settings. We examine the replicative validity of the simulated populations by contrasting them to the observed survey data sets on which the parameter estimation was based. We then compare the simulated life courses to aggregate cohort measures of fertility and partnering for the four countries, published by national statistical offices or the Human Fertility Database (2019). This allows us to assess the replicative validity of our simulated family life against external data sources.[9] Furthermore, the latter data sources include more recent information on younger cohorts and thus allow a first assessment of the predictive validity of the simulations.

[9] In addition, such a comparison also examines whether the survey data are appropriate for parametrisation of the model (data validity).

5.1 Validation

To test replicative validity, we compare the simulated and observed life courses along three dimensions – age, parity, and partnership status. In particular, we tabulate the birth and union status by age for each cohort and country setting for both the simulated and observed survey data. We restrict the comparison to the ages where at least 90% of the women in each cohort can be observed in the survey.

The results are shown as heat plots of the difference between simulated and observed proportions of women by parity and partnership status at exact ages from ages 15 to 50 years. The purple shading denotes that the share of women in a given birth and union status is lower for the simulated than for the observed data at the respective exact age, the green colour that it is higher, and the light colour indicates no difference.

Figure 2 shows results for the Scandinavian birth cohorts, and Figures A-1–A-2 in Appendix C show the plots for Italy and Great Britain. Overall, we find that the combined birth and union states by age usually differ by less than 0.5 percentage point and only very rarely by more than 2 percentage points between the observed samples and simulated populations. The noticeable differences are mainly from ages 18 to 27 for never-partnered and married women born in the 1940s and 1950s, i.e., in the age ranges where family-state transitions are frequent. This suggests that differences might be partly due to small variations in timing and/or measuring of ages at events (exact ages in simulated data vs. month–year format in observed samples). In addition, due to the large size of the simulated population, the simulations produce smooth age profiles, whereas they tend to fluctuate in the observed samples, even considerably where counts are low. This may contribute to the minor differences between simulated and observed data, when measured at exact ages.

Never-partnered women with no or one birth are slightly overrepresented in the simulated data, except around ages 20–25, where single childless women are underrepresented. The simulation of married women exhibits a tendency to undercount married women of lower parity and to overcount those of higher parity in almost all cohorts of the three country settings. Nonetheless, the simulated numbers remain quite close to the observed numbers and the difference in such cases is prevalently less than 2 percentage points.

Figure 2: Heat map of difference in frequencies of birth and union status between simulated and observed female family life courses at exact ages by 10-year cohorts, Norway and Sweden combined

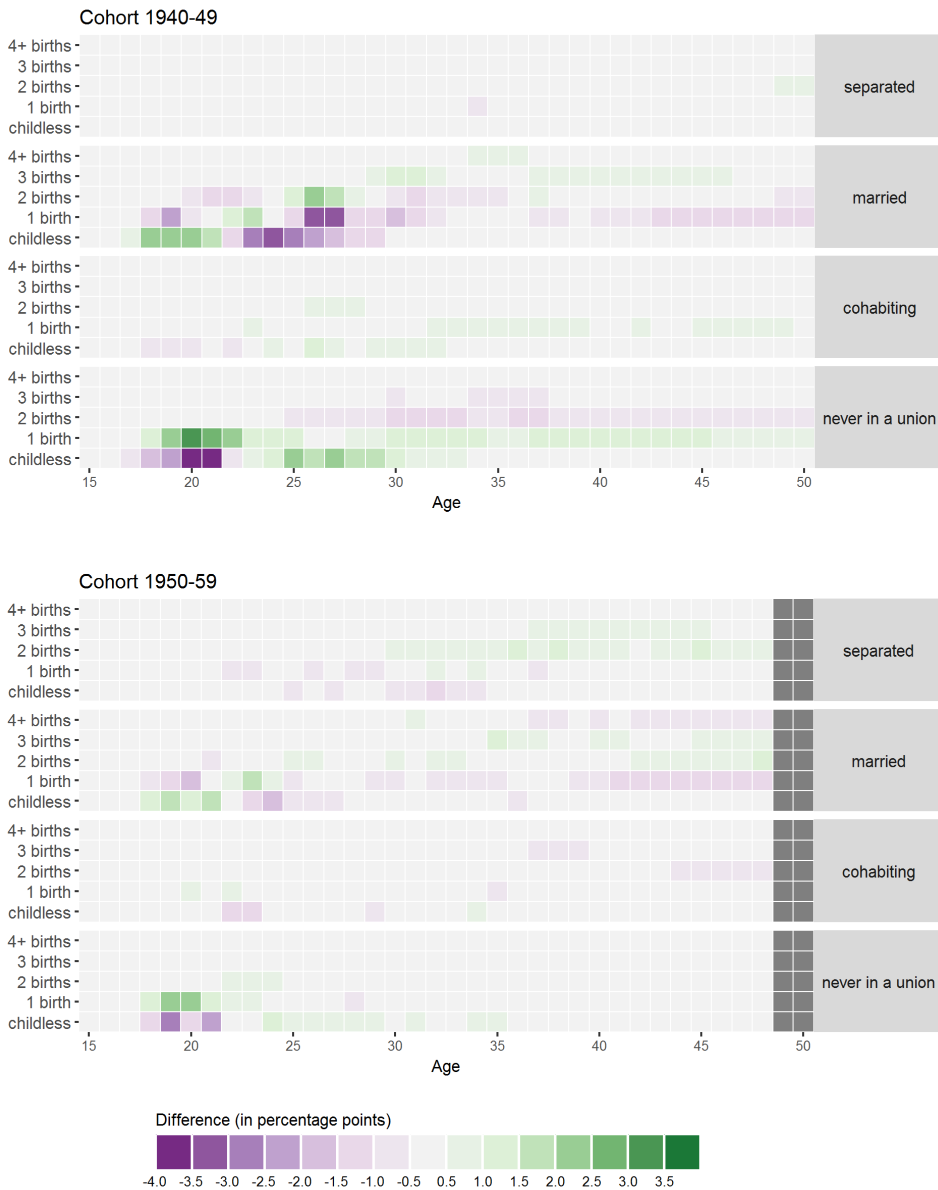
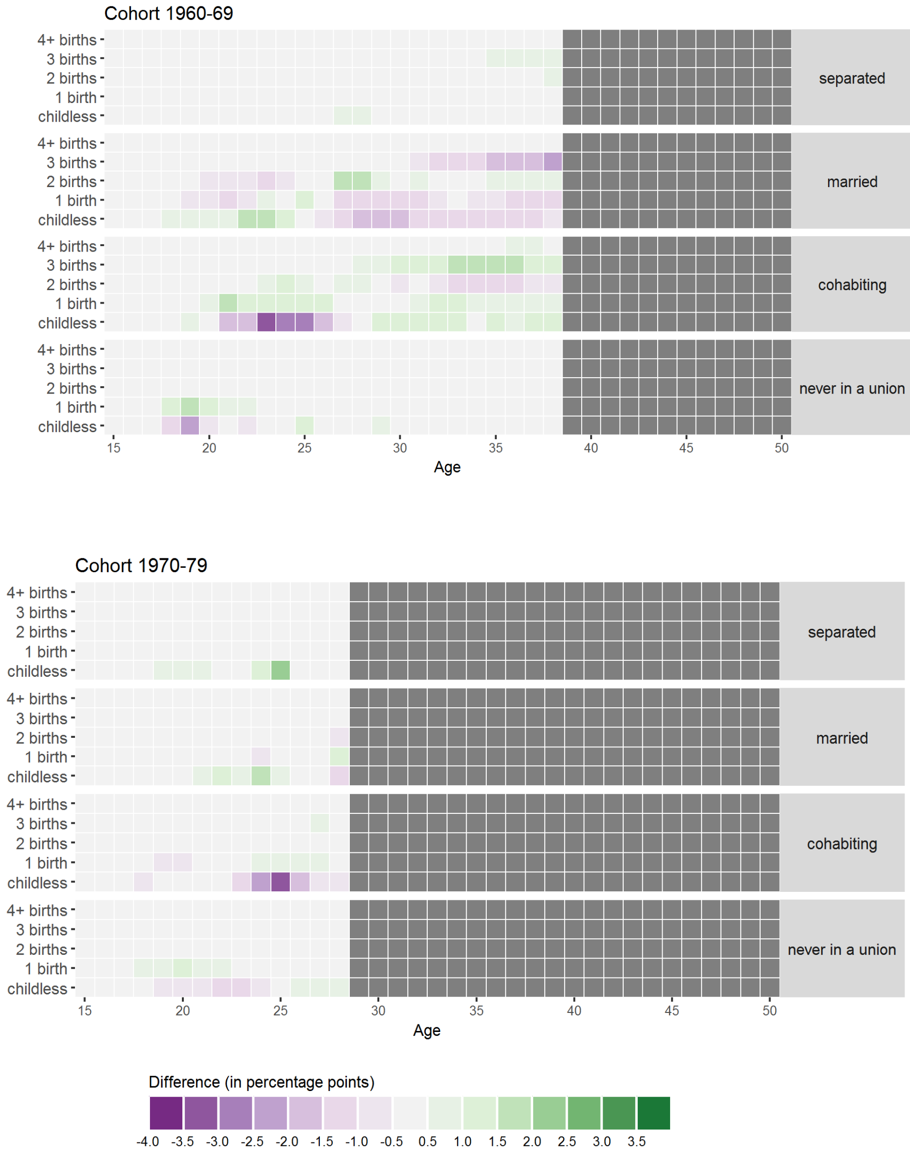


Figure 2: (Continued)



Summing up, the simulations replicate the distribution of number of births and union events across age very well, and thus resemble remarkably the observed real-world family life courses as observed in the respective surveys in each cohort and country setting.

5.2 Comparison with published national macro-level indicators

Besides the validation from survey data, we compare selected demographic indicators of the simulated populations to available administrative cohort statistics from each country. We derive the proportion of women by age and parity and the cohort proportions of ever married and ever divorced women by age for the comparison to national cohort data. For corresponding numbers from national cohort statistical resources, we use data from the Human Fertility Database (2019) and from the national statistical offices of Italy (ISTAT 2018), Great Britain (Office of National Statistics 2018a, 2018b, 2019), Norway (Statistics Norway 2018), and Swedish registers (Thomson 2018).[10] Published national single-year cohort proportions were, if not otherwise noted, aggregated to 10-year equivalents by applying the year of birth distributions in the respective survey data.

The following paragraphs evaluate the replicative and predictive validity of the simulated family life courses for the decennial cohorts of women born between 1940 and 1979. Because in the parameter estimation for the most recent cohort of women born between 1980 to the mid-1990s additional assumptions had to be postulated (cf. section 4), we discuss the microsimulation output for that cohort separately.

5.2.1 Family life courses for women born between 1940 and 1979

Figures 3–8 plot for British women and Figures A-3–A-12 in Appendix D for Norwegian, Italian, and Swedish women, at each age, the proportion of women in the cohort already having at least one, two, three, or four children; ever-married; and ever-separated from a marital union; for simulated data (red circles), observed survey data (blue triangles), and national statistics (green squares). As expected, the close correspondence of birth and union events by age results in an almost perfect match between the simulated populations and the observed samples of cumulative fertility and of marriage and separation indicators across age. In comparison to national statistics, the simulated fertility, marriage, and divorce indicators also approximate quite closely those obtained from national statistics, even beyond the ages observed in the underlying surveys in all countries. Minor differences are only visible for higher birth orders, with slightly lower

[10] See Appendix D for information on the limited availability of comparable national indicators.

simulated fertility than in national statistics, consistent with our restricting the observed samples to native-born women (Figures 5, 6, A-8), and in the timing of marriage with about a year difference between the simulated data and corresponding national data (Figure 7 and A-13). More pronounced differences are only visible for divorce indicators for the two most recent British cohorts (Figure 8). The simulation predicts higher shares of marital unions dissolved than the national divorce statistics, particularly at older ages, which may be partly due to parameter uncertainty. A detailed discussion of the differences between simulated and national cohort indicators presented, including data availability issues, can be found in Appendix D.

In sum, we find that the simulation model also satisfactorily replicates the observed family change in European countries across decennial cohorts for women born between 1940 and 1979 beyond the ages at the underlying survey (predictive validity). For instance, Figure 3 depicts the postponement of motherhood in Great Britain: While about 59% of the simulated British women born in the 1940s already had a birth by the age of 25 the share dropped to 35% among women born in the 1970s. The corresponding shares declined from around 65% to around 35% in the Scandinavian countries and from 56% down to even 23% in Italy (cf. Figures A-3, A-7, and A-11). At the same time, simulated ultimate childlessness rose in Great Britain and Italy to around 20% for women born in the 1970s, with no change in the Scandinavian countries. Similarly, the simulated progression to higher-order births remained relatively stable in the two Scandinavian countries, while the proportion of mothers with at least two, three, or four births declined across cohorts in Great Britain and Italy.

While marriage was early and universal for the 1940s' cohort of British women, later-born cohorts increasingly postponed or even forwent marriage in Great Britain, according to observed and simulated data across British female cohorts (cf. Figure 7). Such a trend of postponement and retreat from marriage can also be found for Italian and Scandinavian female cohorts, albeit at a different pace and level.[11] At the same time, simulated divorce rates rose across cohorts, but stabilized or even declined among more recent cohorts for Great Britain and Scandinavian countries. Furthermore, the microsimulation model allows us to distinguish the well-known spread of unmarried cohabitations and repartnering across these cohorts. A variety of further family life indicators, such as the share of nonmarital childbearing, family instability, childbearing across partnerships, etc., can be retrieved from the microsimulation output, and are available on request.

[11] Results available on request.

Figure 3: Cumulative proportion of women with at least one birth, by age, for simulated and observed data for British women, and vital statistics for England and Wales, by 10-year birth cohort

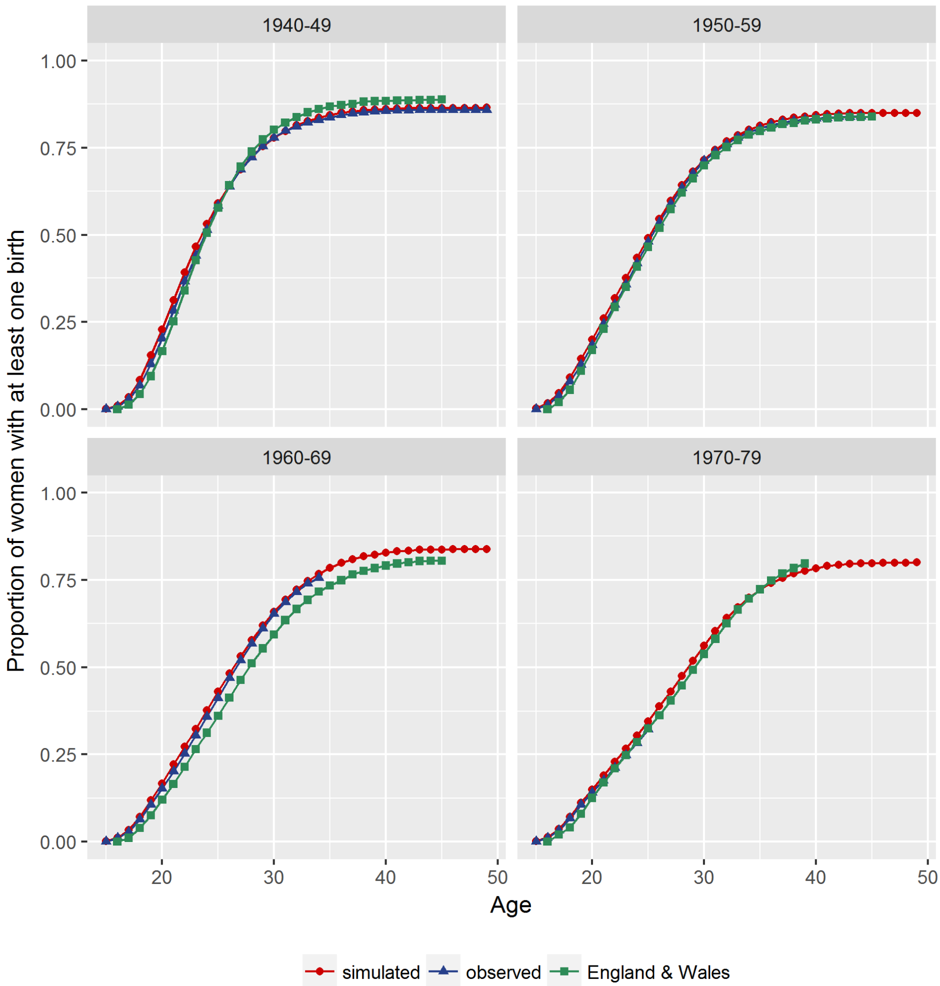
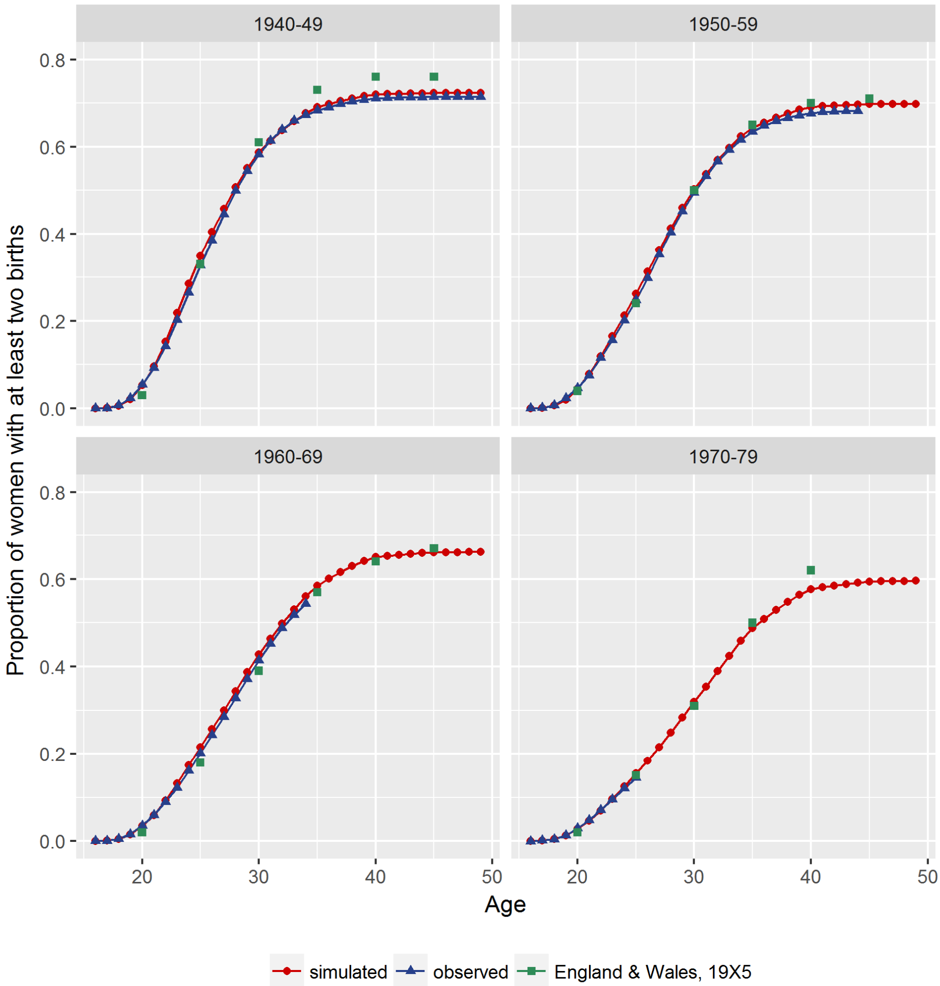
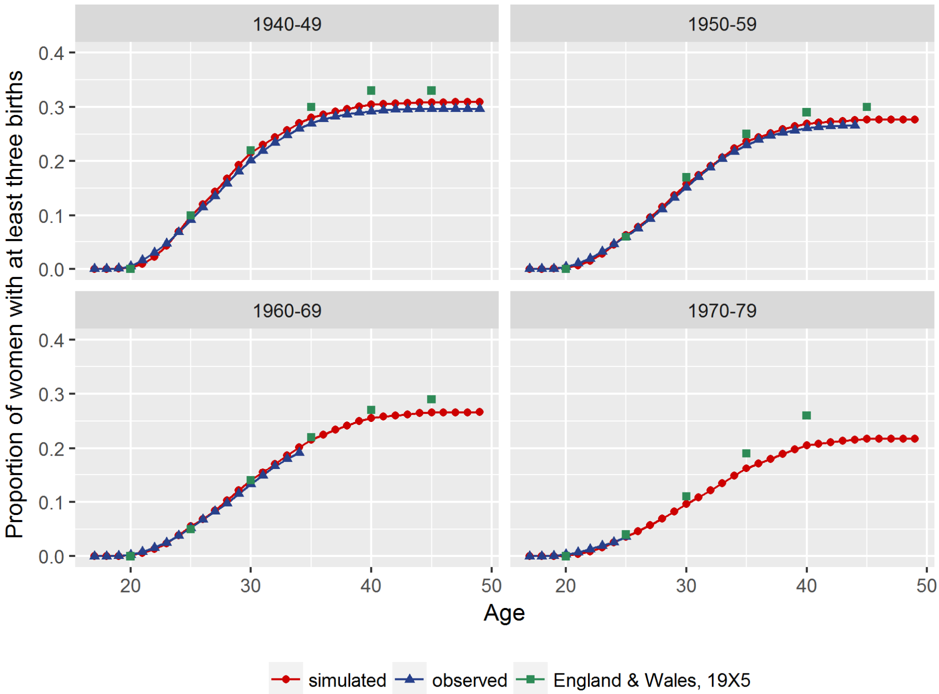


Figure 4: Cumulative proportion of women with at least two births, by age, for simulated and observed data for British women, and vital statistics for England and Wales, by 10-year birth cohort



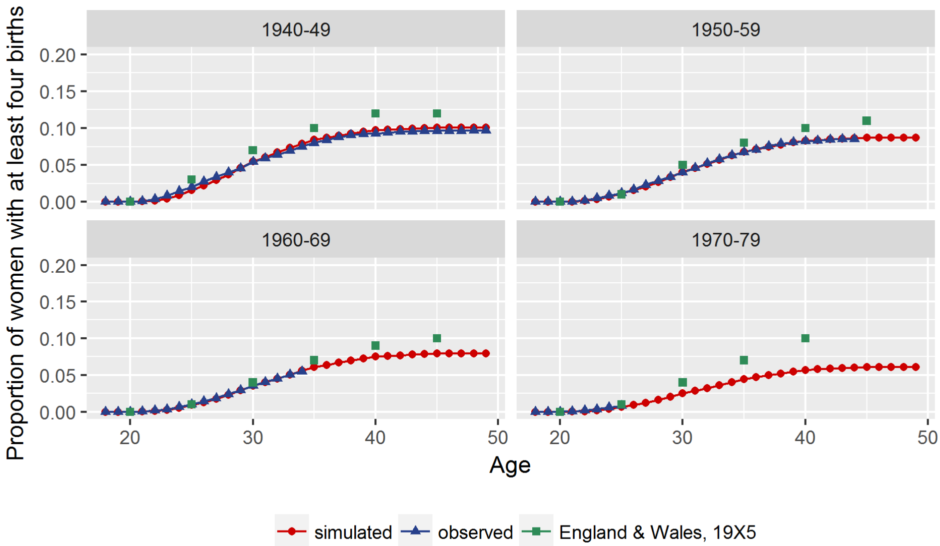
Note: Age-specific data from vital statistics for England and Wales were only available for selected cohorts. We chose the middle single-year birth cohorts, denoted by "19X5", as reference for the surrounding 10-year birth cohorts, i.e., 1945 for 1940–1949, 1955 for 1950–1959, etc.

Figure 5: Cumulative proportion of women with at least three births by age for simulated and observed data for British women, and vital statistics for England and Wales, by 10-year birth cohort



Note: Age-specific data from vital statistics for England and Wales were only available for selected cohorts. We chose the middle single-year birth cohorts, denoted by “19X5”, as reference for the surrounding 10-year birth cohorts, i.e., 1945 for 1940–49, 1955 for 1950–1959, etc.

Figure 6: Cumulative proportion of women with at least four births, by age, for simulated and observed data for British women, and vital statistics for England and Wales, by 10-year birth cohort



Note: Age-specific data from vital statistics for England and Wales were only available for selected cohorts. We chose the middle single-year birth cohorts, denoted by “19X5”, as reference for the surrounding 10-year birth cohorts, i.e., 1945 for 1940–49, 1955 for 1950–1959, etc.

Figure 7: Cumulative proportion of women ever-married, by age, for simulated and observed data for British women, and vital statistics for England and Wales, by 10-year birth cohort

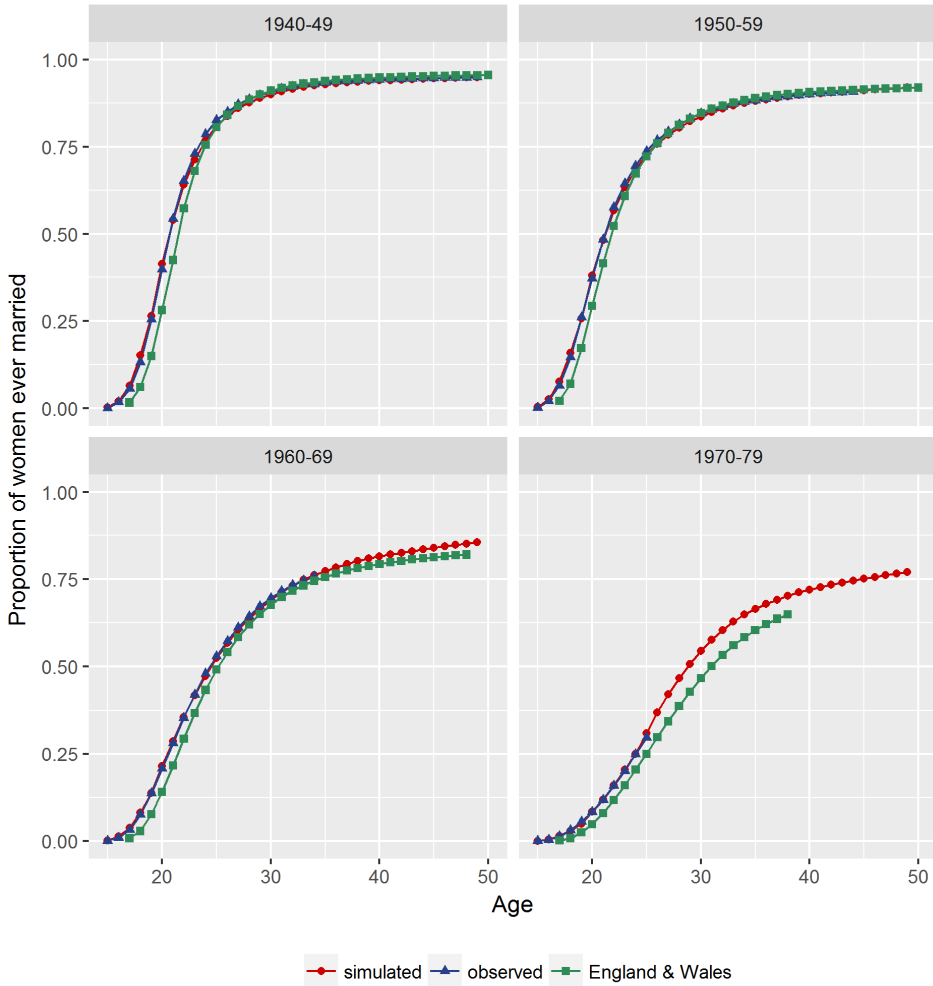
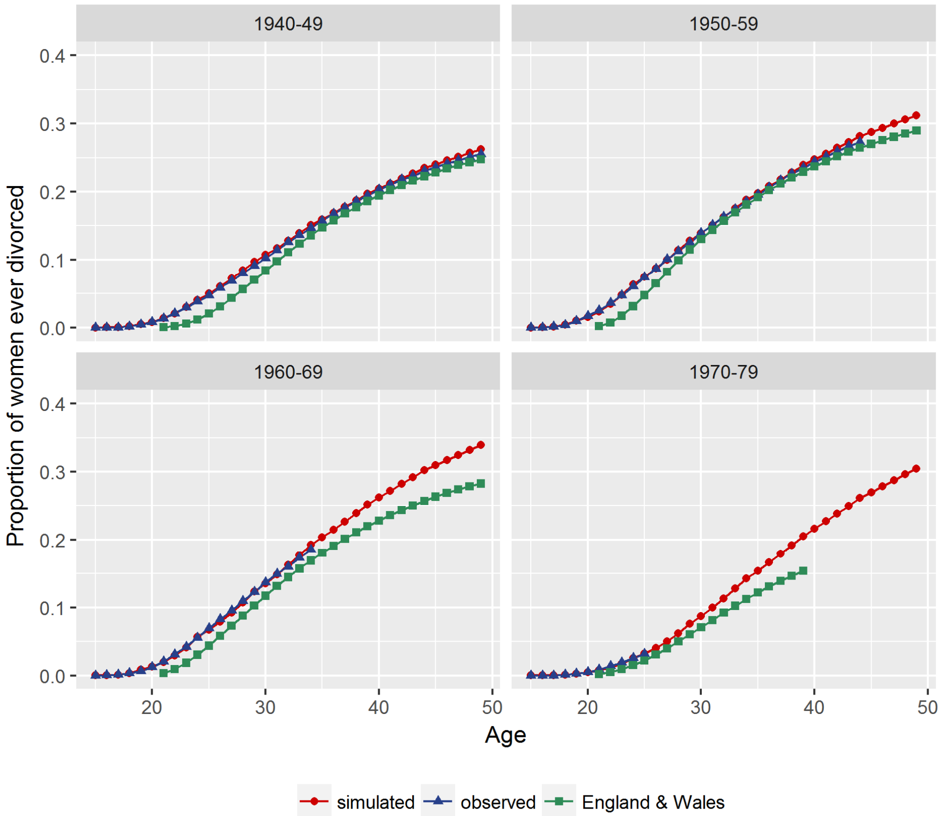


Figure 8: Cumulative proportion of women ever separated from a marital union, by age, for simulated and observed data for British women, versus cumulative proportion of women ever divorced for England and Wales (vital statistics), by 10-year birth cohort



Note: While the national statistics are constructed on age at legal divorce, we used reported age at separation of marital unions for the observed and simulated family life courses in order to avoid overlapping partnerships.

5.2.2 Family life courses for women born after 1980

In the hazard regression we also included retrospective information on women born from 1980 to the mid-1990s. These women were on average around 22 years old at the time of the survey. Hence, parameter estimation with separate cohort indicators was not feasible for family events usually occurring later in life (e.g., higher-order births or union events) and we had to combine the experience of the cohorts of women born in the 1970s with those born after 1980. The simulations based on the parameters estimated for women born after 1980 yield – for all countries, albeit on different levels – a continued postponement of motherhood and retreat from marriage, as well as further increases in the share of births in nonmarital cohabitation and second and higher unions.

In order to preliminarily gauge the validity of the latter simulated family life trajectories, we compared them with the real-world equivalent from recent national cohort statistics for women born between 1980 and 1989, as far as available. Figures 9–12 show the cumulative proportions of women with at least one, two, three, or four births for the simulated data versus corresponding data for England and Wales (Office of National Statistics 2018a), Italy (ISTAT 2018), and Norway and Sweden (Human Fertility Database 2019). Overall, we find that the simulations approximate the national cumulative fertility indicators for all birth orders below age 30 very closely. For the marriage process, corresponding indicators for the 1980–1989 cohort at similar ages are not available. Thus, the simulated family life trajectories for these cohorts should only be used with caution until more recent data becomes available to judge their validity.

Figure 9: Cumulative proportion of women with at least one birth, by age, for simulated and national data for women born in 1980–1989, by country

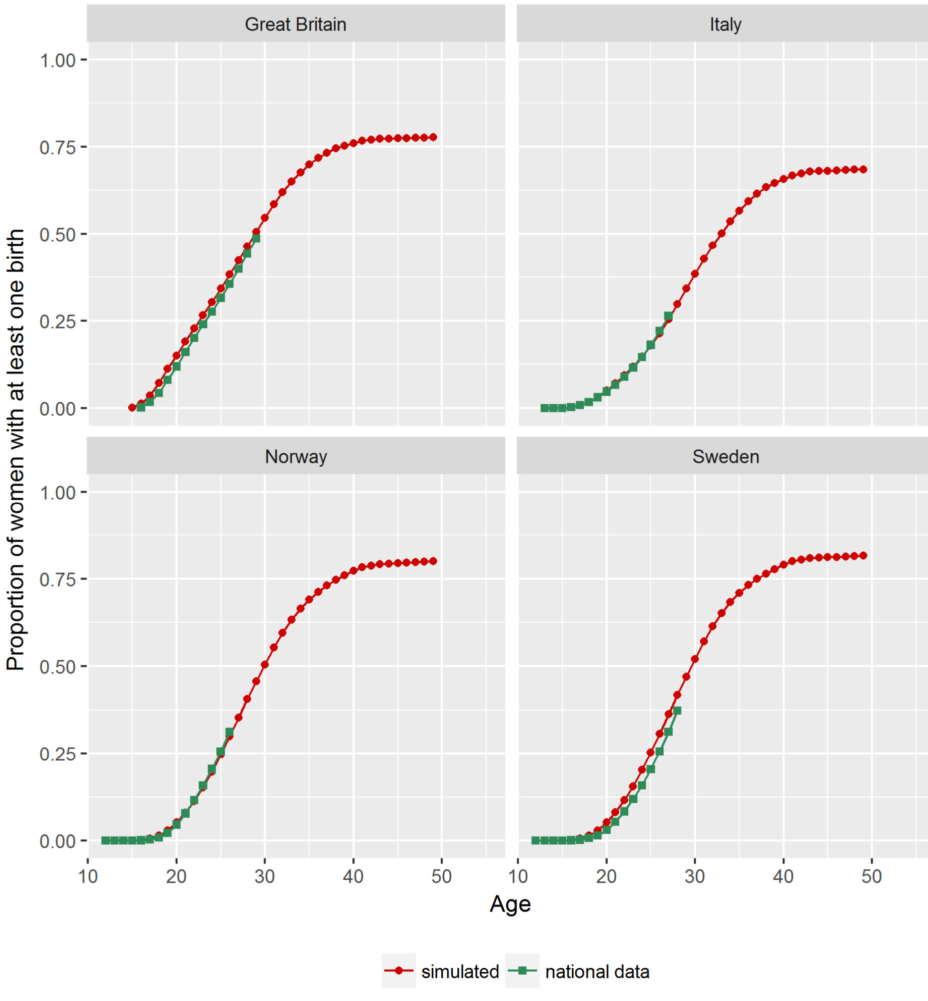


Figure 10: Cumulative proportion of women with at least two births, by age, for simulated and national data for women born in 1980–1989, by country

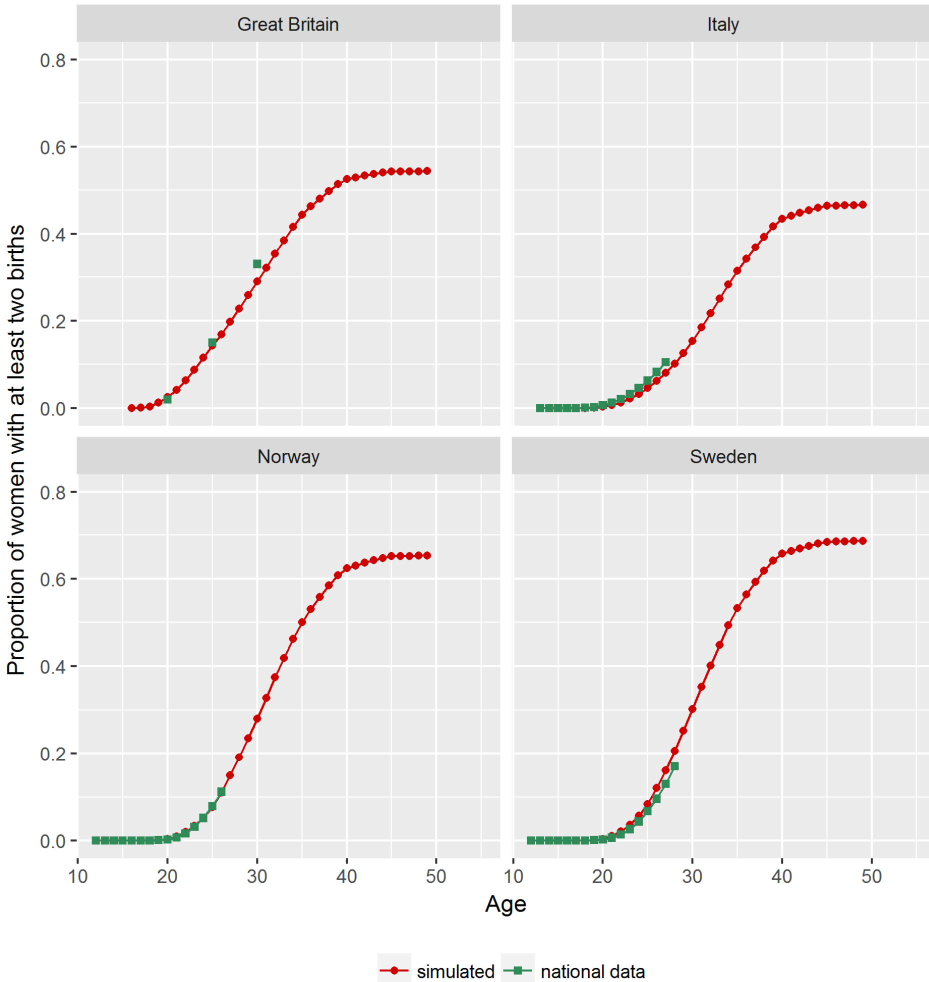
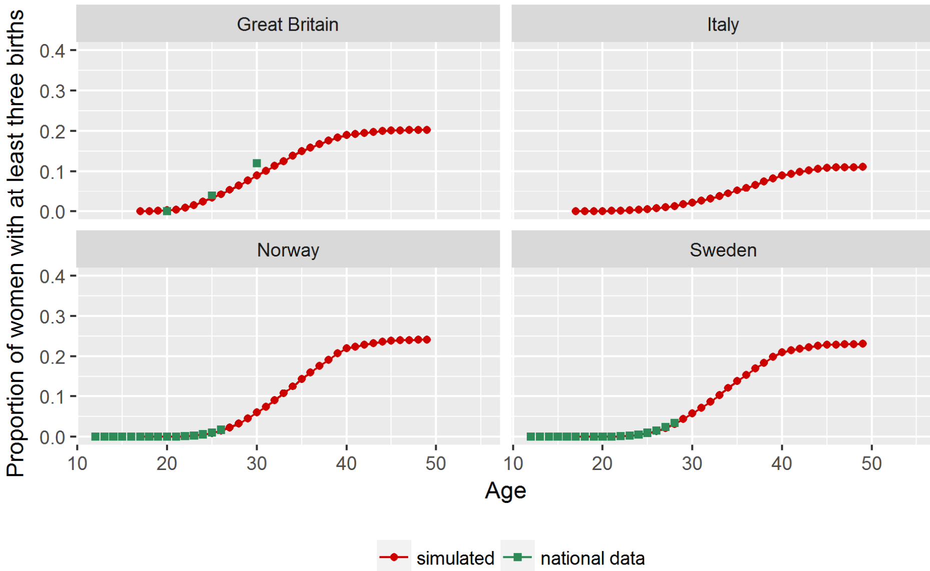
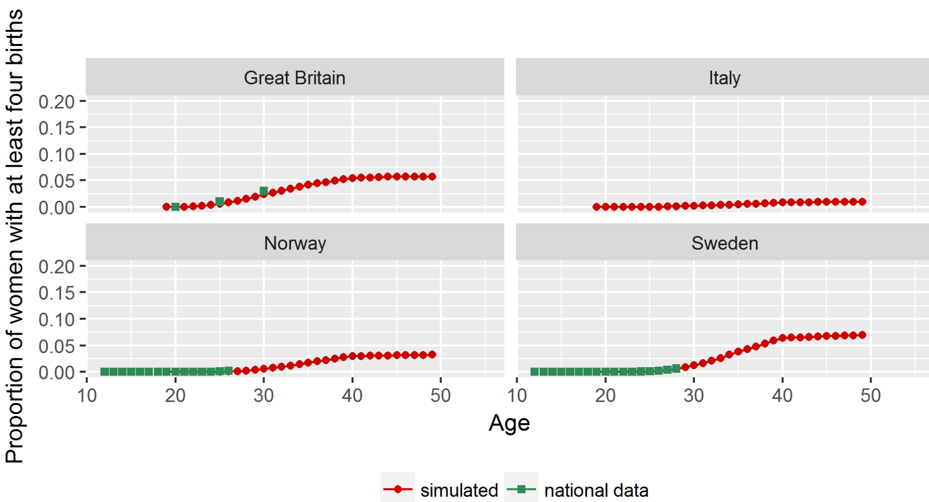


Figure 11: Cumulative proportion of women with at least three births, by age, for simulated and national data for women born in 1980–1989, by country



Note: Italian national data not available.

Figure 12: Cumulative proportion of women with at least four births by age for simulated and national cohort data for women born in 1980–1989, by country



Note: Italian national data not available.

6. Conclusions

The present study illustrates how microsimulation can be employed to link micro-level associations to macro-level outcomes in family life course research; or, put differently, to show how single family-building processes together shape macro-level family change. In the course of the paper we have described in detail how to set up a microsimulation model based on theoretical reasoning, how to parameterise it, and how to simulate and validate the hypothetical family life courses.

An important feature of our microsimulation model is that it explicitly takes into account the complex interrelationships between individual childbearing and partnership dynamics. To our knowledge, this is the first simulation model that not only models the multifaceted interactions between childbearing and partnership, but also differentiates between unmarried cohabitations and marital unions. Thus, the model implicitly controls for associations between cohabiting parenthood, partnership instability, repartnering, prior childbearing, etc. In fact, the purpose of the model is to gain a better understanding of the mechanisms through which the interrelated, individual partnership and parenthood processes are linked over the life course and – through aggregation – to obtain |macro-level family outcomes. In addition, the simulations predict childbearing and partnership trajectories for cohorts of women who are still of childbearing age.

A key requirement for a microsimulation is that it produces a synthetic population that closely resembles a real population and thus achieves validity (Willekens 2009). However, validity should be assessed not only on how well it replicates the observed population, but also on whether the dynamical system of the simulation model "truly reflects the way in which the real system operates to produce this behaviour" (Zeigler 1985: 5, cited in Troitzsch 2004; see also Sargent 2010; structural or conceptual validity). Accordingly, we extensively reviewed theories and empirical evidence on the interaction between childbearing and partnership to ensure that our model assumptions were correct and to capture the key mechanisms throughout the family life course. Using survey data for Italy, Great Britain, and two Scandinavian countries to parameterise the model, we found that the hazard estimates are indeed consistent with previously observed micro-level relationships between childbearing and partnering for the respective country settings, overall and across cohorts.

At the aggregate level, we tabulated the combined parity and union status distributions of the simulated cohorts by age and compared them to the observed survey data up to the ages where the latter can be observed (replicative validity). Altogether, the simulations approximate the number of births and union events across age very closely and replicate very well the family life courses in the respective surveys in each cohort and country setting.

In addition, we contrasted selected demographic indicators of the simulated populations to their real-world equivalents from national administrative data or the Human Fertility Database. This comparison not only confronts the simulated data with an independent data source that often contains more recent information (predictive validity) but also evaluates whether the survey data is appropriate for the parameterisation of the simulation model (data validity). Again, we find a remarkably close fit of the simulated indicators with the real-world counterparts, particularly in the progression to the first two births, and – consistent with our restricting the observed sample to native-born women – only slightly lower values for simulated third and fourth births. Notably, the correspondence exists both in the eventual quantum and in the timing across age, even beyond the ages to which the respondents in the original surveys could be observed.

However, the comparison is limited by data availability, particularly for partnership processes. Cohort proportions of ever married and ever divorced were only available for England and Wales. While the simulations replicated the summary indicators of marriage and divorce by age very well for older cohorts, somewhat more pronounced differences were visible for the later cohorts for the British data. To further evaluate the simulated partnership processes, in particular for the most recent cohorts, more recent data are needed for Great Britain as well as for the other country settings. This relates specifically to the simulated family life courses for women born since the 1980s. Although a first assessment of cohort fertility indicators by age ascertains a close correspondence of the simulation with most recent national cohort data below age 30, predictions of later life events should only be used with caution for the latter cohort.

The validations confirm that the simulated family life trajectories resemble their real-world equivalents in the three country settings rather closely. Indeed, we find that the microsimulation model replicates well the observed family change, i.e., the decline and postponement of marriage and motherhood and the increasing prevalence of cohabitation, nonmarital childbearing, union instability, and repartnering. Most notably, the model consistently links the estimated micro-level associations of childbearing and partnering with the changing macro-level family patterns described above. Thus, this microsimulation model is very suitable for exploring how individual childbearing and partnership processes shape family life trajectories and how they relate to macro-level family change across cohorts.

In particular, Thomson, Winkler-Dworak, and Beaujouan (2019) explore the contribution of the rise in cohabiting parenthood to family instability using this microsimulation model. They seek to identify the mechanisms through which the macro-level association between cohabiting parenthood and parental separation arises from the micro-level associations. They decompose the change in parental separation rates into components that can be attributed to shifts in union status at first birth –cohabiting versus married – and to the change in separation rates in both unmarried cohabitation and marriage across mothers' cohorts.

In section 2.3 we outlined a further potential application of the model, namely disentangling the complex theoretical link between the spread of cohabitation and aggregate fertility levels. In short, increasing prevalence of cohabitation may depress aggregate fertility levels if cohabitation delays family formation and parenthood. But if childbearing in cohabitation becomes widespread, the younger ages of cohabiting couples in contrast to married couples may enhance fertility levels, as younger ages at parenthood are usually associated with higher ultimate family size. Whether this fertility-enhancing effect accrues depends on differences in the stability of cohabiting and married unions and on the net impact of union instability on fertility. The ambiguous effect of union instability on fertility has been previously studied in a similar framework (Thomson et al. 2012), but that analysis did not differentiate whether a cohabiting or marital union had been dissolved. The microsimulation model presented here models unmarried cohabitation versus marriage, and thus should provide further insight into the links between union instability, repartnering, and fertility.

As noted above, our simulations are based on the childbearing and partnership histories of native-born women. Childbearing and partnership behaviour not only differ between native-born and immigrant women but also among immigrant groups (e.g., Andersson 2004; Hannemann and Kulu 2015; Mussino and Strozza 2012, Sobotka 2008; Tromans, Jefferies, and Natamba 2009). However, there is only limited research on cumulated differentials over the life course (Wilson 2020). An extension of our simulation framework to immigrants' family experiences is beyond the scope of this paper but might provide useful insight into how differentials in childbearing and partnership behaviour by ethnicity interact and accumulate over the life course.[12]

The richness of potential research questions demonstrates the wide applicability of microsimulations in the context of family change. However, their usefulness depends on the validity of the underlying models. As discussed above, these models are only based on demographic variables and do not incorporate variation in parental background, place of birth, education, or other experiences and characteristics that may influence life course choices. Future research should address whether differences in birth and union processes related to variation in these variables reinforce or offset throughout the family life course.

The high validity of our model suggests that the construction of counterfactual scenarios ('What would have happened if?') would yield valuable results. This would consist in exploring the impact of potential changes in very specific microbehaviours on macro indicators. Coming back to the previous example, one could, for instance, ask the question: How would fertility levels have differed if births in cohabitation had remained rare while cohabitation was spreading? Such explorations may help better understand very low fertility levels in countries where cohabitation has spread recently but births still only take place in marriage (e.g., in Japan and South Korea, see Fukuda 2020). More generally, the impact of the change in marriage quantum and timing on completed fertility could be explored depending on how much nonmarital births had spread.

Finally, 'what if' scenarios might prove useful in the light of current developments. The COVID-19 pandemic has been altering many domains of life, including the family. Due to the social, economic, cultural, and psychological consequences of the pandemic, changes in the timing of family transitions are expected, such as postponement of cohabitations, marriages, and fertility and accelerated separation and divorce (Settersten et al. 2020; Aassve et al. 2020; Lappegård, Kristensen, and Mamelund 2020). Simulating scenarios of these anticipated effects might help to gauge the potential impact of the ongoing pandemic on individuals' family life courses and on fertility and family structure at the population level.

[12] An application to migrant family dynamics would require an extension of the simulation model, as immigrants' family formation rates depend on the timing of the migration event (Toulemon 2004; Andersson 2004).

7. Acknowledgments

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