Chapter 6
Agent-Based Modeling of Family Formation and Dissolution

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6.1 Introduction

The questions of 'who marries whom?' and 'whose marriage remains intact?' are important pieces in the puzzle of social inequality (Lewis 2016; Mare 1991; Tach 2015). The more people tend to marry members of their own social group, the more unequal will be the distribution of advantages and disadvantages across families in one generation and the more likely it becomes that existing inequalities are transferred to the next (Blossfeld 2009; Hout 1982; Kalmijn 1991). Members of disadvantaged groups are also more likely to live in non-intact families and the offspring of such families tends to perform worse academically and economically than the offspring of intact families. By that, existing inequalities can become further reinforced across generations (Tach 2015).

Prior research has typically assumed that patterns of family formation and dissolution derive from an interplay between preferences and opportunities (Kalmijn 1998; Schmitz 2016; Schwartz 2013). People desire certain characteristics and traits in their partners, such as physical attractiveness, intelligence, and status (Buss et al. 1990; Hitsch et al. 2010a; Kalmijn 1998). Such preferences can be culturally imprinted (Eagly et al. 2009; Zentner and Eagly 2015; Zentner and Mitura 2012), can be affected by normative influence from significant others (Schwartz and Han 2014), and may be partially hard-wired by evolutionary processes (Buss 1989). No matter their source, the extent to which men and women can realize their partner preferences is constrained by the availability of people with the desired characteristics in the social contexts in which they can meet each other, such as schools, neighborhoods, and workplaces (Blossfeld and Timm 2003; Feld 1981;

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Kalmijn and Flap 2001; McKinnish 2007; Nielsen and Svarer 2009; Schoen and Wooldredge 1989). These constraints can lead to adjustments in people's partner aspirations and search behavior, and thereby shape observed family patterns (Lichter 1990; Oppenheimer 1988; Todd et al. 2013).

Despite the primacy of preferences and opportunities in earlier research, we still know relatively little about how they interact in generating observed family patterns (Lewis 2016). One reason for this are differences in the availability of data at the micro and macro levels of analysis (cf. Billari et al. 2003; Todd et al. 2005). There are many large-scale data sets that allow us to draw detailed pictures of family formation and dissolution, sometimes covering long time periods (e.g., Torr 2011) and many countries (e.g., Kalmijn 2013). However, such data sets often do not contain detailed information about the preferences and normative influences that have guided the observed partnering and dissolution decisions. To address this issue, researchers have started to employ new types of data. For example, there is an increasing number of studies that use data from speed-dating events and dating websites (e.g., Finkel et al. 2007; Fisman et al. 2006; Hitsch et al. 2010a, b; Schmitz 2016; Skopek et al. 2011b). In these contexts, it is possible to collect information about people's partner preferences (e.g., through survey items in registration forms), the opportunity context (e.g., through information about the demographic characteristics of those who attend a dating event), and even the interactions that occur between prospective partners (e.g., through logs of contact requests on dating websites). But using the insights gained from such sources to determine which processes might have been involved in shaping family patterns at the population level is difficult. Processes that have been observed at the micro level, possibly in spatially and temporally constrained contexts, may combine in unexpected ways when they occur in large and heterogeneous populations, whose members interact over extended periods of time (Van Bavel and Grow 2016).

In this chapter, we introduce agent-based computational (ABC) modeling as a way to deal with some of the challenges that the study of family formation and dissolution poses. In ABC modeling, researchers make explicit assumptions about the preferences and constraints that guide people's family decisions. These assumptions are then implemented in formal models that are submitted to computational simulations of familial behavior in potentially large and heterogeneous populations, along with relevant and available empirical information. The results of these simulations make it possible to (1) assess whether a given set of preferences may have plausibly been involved in generating observed familial behavior given the constraints that people face and (2) to assess whether very different sets of preferences may generate similar patterns. By that, ABC modeling provides an effective tool for combining the micro and macro levels of analysis, and helps to further our understanding of the interplay between preferences and opportunities (Van Bavel and Grow 2016; Billari et al. 2003; Gilbert and Troitzsch 2005; Grow and Van Bavel 2018; Macy and Flache 2009; Squazzoni 2012).

We illustrate these capabilities of ABC modeling with three examples from our own research in the areas of assortative mating and divorce. In particular, we aim to illustrate how ABC modeling can be used to illuminate the processes that link the micro level with the macro level in family formation and dissolution. In each of the three studies, we draw on existing marriage market data to generate plausible opportunity structures. We then explore the implications of different sets of mate preferences and assess how well the resulting family patterns match empirically observed patterns. After discussing the implications of the results of the three studies, we close the chapter by providing some guidelines for using ABC modeling in family research.

6.2 Three Examples of ABC Modeling

6.2.1 The Reversal of the Gender Gap in Educational Attainment and Assortative Mating

Our first example focuses on the link between changes in men's and women's educational attainment and patterns of educational assortative mating. The relative educational attainment of men and women has changed dramatically over the last decades. Until the 1970s, it was mostly men who participated in higher education, but the number of women in tertiary education has increased since then. Nowadays, the gender imbalance in higher education has turned to the advantage of women in many Western countries and also other parts of the world (Schofer and Meyer 2005). These changes had implications for patterns of educational assortative mating. In marriages, spouses tend to be similarly educated (homogamy), but in the past, if they differed in their educational attainment, the husband used to be more educated than the wife (hypergamy). This has changed with the gender-gap reversal in education. Today, if there is a difference in spouses' educational attainment, the wife is likely to be more educated than the husband (hypogamy) (De Hauw et al. 2017; Esteve et al. 2012, 2016; Van Bavel et al. 2018).

One interpretation in the literature holds that changes in educational attainment and assortative mating might have been linked through changes in people's partner preferences (Esteve et al. 2012). This appears plausible from a social exchange perspective (Edwards 1969), which assumes that marriage is a form of exchange, in which people seek partners who maximize their rewards, compared to the rewards they might derive from remaining single or from forming a union with somebody else. Given the lower economic opportunities that women had compared to men in the past, women's economic wellbeing largely depended on the income that their partners provided. Marriage therefore often took the form of an "exchange of a man's economic resources for a woman's social and domestic services" (Schoen and Wooldredge 1989, p. 466; see Becker 1981 for a similar argument). The male-breadwinner/female-homemaker family model was therefore dominant and both men and women were aversive of a situation in which a wife had a higher socioeconomic status than her husband. Yet, as women's and men's educational attainment, and therefore also their economic opportunities, became more similar over time, so too may have their preferences for socioeconomic status in their partners (cf. Oppenheimer 1988). As a consequence, people may have become less aversive of a situation in which the wife has higher socioeconomic status than her husband.

There is some empirical evidence that suggests that men's and women's partner preferences have indeed converged to some extent over the last decades (Zentner and Eagly 2015), but women still tend to attach more importance to the economic resources of their partners than men (Li and Kenrick 2006). The agent-based model that we present in Grow and Van Bavel (2015) makes it possible to assess whether one needs to assume that preferences have changed in order to explain the link between changing patterns of educational attainment and assortative mating, or whether changes in the opportunity structure alone would have been sufficient.[1]

6.2.1.1 The Model

Every simulation run starts with an initial population of single male and female agents. The core demographic structure of this population is initialized based on characteristics observed empirically in 1 of 12 European countries in 1921 (Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Netherlands, Portugal, Spain, Sweden, and United Kingdom). After this starting population has been created, the simulation proceeds in iterations (also called simulation steps). Ten simulation steps represent one simulation year and each simulation run stops in the simulation year 2012.[2] Over the course of a given simulation run, agents grow older, enter school, enter the marriage market (i.e., start looking for a spouse), leave school, reproduce, and die at some point; the order of these life events can vary from agent to agent.

Preferences and Partner Search

The model focuses on the social status that people desire in their partners. In line with earlier research, the model breaks social status down into a cultural and an economic component. More specifically, earlier research suggests that men and women desire partners who possess similar cultural resources (e.g., similar world views, manners, cultural tastes, etc.), but they also prefer partners who possess high economic resources (Kalmijn 1998). Empirically, people's cultural resources have been operationalized by their educational attainment and their economic resources have been operationalized by their earnings prospects (given their educational

[1] Here we describe only the most important aspects of the model. Additional details are provided in Grow and Van Bavel (2015).

[2] We chose this simulation period based on the empirical input data that was available for initializing the model; see details below.

attainment and occupational choices) (Kalmijn 1994). The model uses this approach and imbues agents with an educational attainment, s_i, and earnings prospects, y_i. Agents' educational attainment s_i can take one of four states, representing the highest educational attainment that a given agent will reach in his/her life (1 = no education, 2 = primary education, 3 = secondary education, and 4 = tertiary education), whereas their earnings prospects y_i can take one of five states ($y_i \in \{1,2,3,4,5\}$), with higher values indicating higher earnings prospects.

Next to this, the model takes into account that age is one of the most important criteria in partner selection (Glick and Landau 1950). Agents are thus imbued with an age (a_i) that can increase from zero to up to 80 years over the course of a simulation run.[3] The model assumes that women tend to prefer partners who are 2–3 years older than they are, whereas men prefer women who are in their mid-20s regardless of their own age, all else being the same. These age preferences are congruent with the predictions of both an evolutionary perspective (e.g., Kenrick and Keefe 1992) and a socio-cultural perspective (e.g., England and McClintock 2009) on partner choice. From an evolutionary perspective, women's fecundity peaks in their mid-20s and men thus are likely to have developed a preference for female partners in this age range, regardless of their own age; this also implies that younger men may be inclined to prefer somewhat older women. Among women, a preference for somewhat older men has been assumed to derive from a trade-off between the fact that older men tend to have higher status than younger men (which makes it easier for them to provide resources for their offspring) and the increased risk of mortality that comes with higher age. From a socio-cultural perspective, women are often evaluated by beauty standards that are best embodied by women who are in their mid-20s. Such beauty standards typically do not apply to men and women's tendency to prefer somewhat older men is based on the often higher status and improved access to resources that tend to be associated with higher age. The available evidence largely supports the predictions that derive from these perspectives. For example, England and McClintock (2009) reported that there typically is an age difference to the disadvantage of women within marriages, and this disadvantage increases with the age-at-marriage of the husband. This suggests that men's age preferences do not change much as they grow older.[4] This notion is further supported by a review of empirical evidence by Bennett (2017), which suggests that according to their stated preferences, men are most attracted to women who are in their early 20s, regardless of their own age. Finally, both Kenrick and Keefe (1992) and Skopek et al. (2011a) reported that compared to older members of

[3]Technically, a_i increases by one in every simulation step. Considering that each simulation step represents a 10th of a year, a_i ranges from 0 to 800 and the value 800 represents the age 80 years.

[4]The average age difference to the disadvantage of wives reported by England and McClintock (2009) increased with the age-at-marriage of husbands, but this increase leveled off for husbands who married after their 30s. As suggested by England and McClintock (2009), this can happen when women are aversive of marrying men who are much older than they are, which makes it more difficult for older men to actually find a young partner who is willing to marry them.

their sex, men in their early 20s have a higher likelihood to feel attracted to women who are slightly older than they are.

Agents use the foregoing characteristics to assess how attractive for marriage they find the opposite-sex members they encounter on the marriage market. This attractiveness is expressed in a single number, the mate value v_{ij}, in which i indexes the evaluating agent and j indexes the agent who is evaluated. The value of v_{ij} is calculated by means of a multiplicative exponential weighting function (cf. Cobb and Douglas 1928) of the form

$$v_{ij} = \left(\frac{S_{max} - \left|s_i - s_j\right|}{S_{max}}\right)^{w_s} \left(\frac{y_j}{Y_{max}}\right)^{w_y} \left(\frac{A_{max} - \left|u_i - a_j\right|}{A_{max}}\right)^{w_a}. \tag{6.1}$$

The first factor in Eq. (6.1) implements the notion that people tend to prefer similarity in cultural resources, represented by their educational attainment. This means that the value of v_{ij} increases as the difference between the educational attainment of i and j becomes smaller, relative to the maximum educational attainment that agents can hold ($S_{max} = 4$). The exponent w_s governs how strongly v_{ij} changes in response to changes in $|s_i - s_j|$, so that higher values of w_s indicate that a larger distance between s_i and s_j is penalized more. The second factor implements the notion that people tend to prefer high economic resources in their partners, represented by their earnings prospects. This means that the value of v_{ij} increases as the earnings prospects of j approach their maximum possible value (Y_{max}=5). The exponent w_y governs how strongly v_{ij} decreases as y_i falls short of Y_{max}, so that higher values of w_y indicate that a larger difference between y_i and Y_{max} is evaluated more negatively. The third factor, finally, implements assumptions about people's age preferences. The model assumes that for male agents, the closer the age of a potential marital partner (a_j) is to the 'ideal' age of 24 years ($u_i = 240$), the higher the value of v_{ij}. For female agents, by contrast, the value of v_{ij} increases the closer the age of j is to the ideal of 2.5 years older than the woman's own age ($u_i = 25 + a_i$).[5] Again, the exponent w_a determines how negatively agents evaluate deviations from these ideals. Note that the values of the exponents w_s, w_y, and w_a can differ between male and female agents. We describe below how we have selected these values for male and female agents in our simulation experiments.

Agents engage in partner search (i.e., enter the marriage market) from the age of 16 years ($a_i = 160$). The search for a partner takes place in random meetings with opposite-sex members. While in school or university, agents are more likely to meet others who are also currently in education at the same level. This captures the structuring effect that the educational system tends to have on meeting opportunities (Mare 1991). The probability that agents will seek out somebody in a given simulation step is determined by their current relationship status and the length of their current relationship. Single agents always seek out and encounter at least one

[5]In Grow and Van Bavel (2015) u_i is denoted α_i; we changed this here to avoid confusing this variable with a_i.

opposite-sex member in each simulation step.[6] For agents who have a partner, k, the probability that they seek out and meet an alternative, j, is attenuated by the length of their current relationship (c_i, measured in simulation steps). The longer agents are already in a relationship, the lower the probability that they will seek out somebody in the current simulation step. This captures the observation that relationship commitment typically increases over time, and that the contact with opposite-sex members tends to decrease with the length of a relationship (Stauder 2006). The exact probability that agent i will seek out an opposite-sex member on the marriage market is defined as

$$\Pr(i \text{ seek}) = e^{-(c_i \beta)}, \tag{6.2}$$

in which β is a parameter that governs how strongly an increase in c_i affects the probability that agent i will seek out somebody in the current simulation step. Generally, if $\beta > 0$ (as we assumed in our experiments), this probability decreases exponentially as c_i increases. For this, it does not matter whether i is only dating his/her current partner or is married (see details regarding this difference below). Hence, agents remain on the marriage market even when they already have a partner/are already married. This makes break-ups and divorce possible. Whenever one agent i meets another agent j, both need to decide whether they want to start dating and leave possible current partners for this. Single agents always consider to date anybody they meet. Yet, agents who currently have a partner (k) only consider dating j when j's mate value is higher than that of their current partner (i.e., $v_{ij} > v_{ik}$). When i actually considers dating j, the probability that i is willing to date j is defined as

$$\Pr(i \text{ willing to date } j) = \left(1 - e^{-(a_i v_{ij} \sigma)}\right) e^{-(c_i \beta)}. \tag{6.3}$$

In Eq. (6.3), the expression in the first set of parentheses holds that the probability that i is willing to date j increases with the attractiveness that i perceives in j (v_{ij}) and with the age of i (a_i). The latter aspect captures the notion that at higher ages, people tend to become less selective in choosing partners, to avoid waiting for 'too long' to make a pick and therefore risking to find no partner at all (e.g., Lichter 1990). The strength of this 'age pressure' is governed by the parameter σ, so that agents become less selective at higher ages as σ increases. In our experiments, we assumed that $\sigma > 0$ and that σ is higher for female agents than for male agents. This implements the notion that women tend to face a greater age pressure in finding a partner, given the biological age limits to fertility and the fact that men tend to prefer women who are in their mid-20s (England and McClintock 2009). The expression on the right-hand side of Eq. (6.3) implies that for agents who currently have a

[6] Technically, agents are selected one after the other (without replacement) to seek out somebody else in a given simulation step. Hence, it can happen that a given agent encounters multiple others in one simulation step.

partner (so that $c_i > 0$), the probability that they are willing to start a relationship with somebody new decreases with the length of their current relationship, representing the notion that over time relationship-specific capital tends to increase, which renders outside alternatives less attractive (Stauder 2006). Note that in each meeting between opposite-sex members, Eq. (6.3) is applied twice, once from i's point of view and once from j's point of view. This implies two independent decisions and only if both agents want to date, they actually start dating (and leave their current partners, if they have one). At the end of each simulation step, agents who are dating have to decide whether they want to propose marriage to their partner or whether they want to accept an existing proposal from their partner. The probability that this is the case is determined by

$$\Pr\left(i \text{ willing to marry/propose to } k\right) = \left(1 - e^{-(a_i v_{ik} \sigma)}\right)\left(1 - e^{-(c_i \beta)}\right). \tag{6.4}$$

Equation (6.4) has a similar interpretation as Eq. (6.3), with the only difference that with increasing relationship length agent i becomes more likely to propose marriage/accept an existing proposal from his/her partner. That is, the older agents become and the more attractive their partner, the more likely they are to propose/accept marriage. This probability increases further with the length of their relationship. Just as dating, marriage is based on two decisions, one by agent i and one by agent k. If one of them proposes marriage to the other, the proposal remains intact until the other accepts this proposal, or until the relationship ceases to exist. Relationships can only cease to exist when one of the two agents dies, or when one of them finds a more attractive alternative and re-partners. For simplicity, there are no other sources of union dissolution in the model.

Opportunity Structures

Within each simulation run, the initial agent population is gradually replaced by new agents and this makes it possible to implement changes in the opportunity structure over several cohorts. To implement plausible opportunity structures, we infused the simulation model with information from two data sources.

The first source are the reconstructions/projections of educational attainment for the period 1970–2050 provided by the International Institute for Applied Systems Analysis/Vienna Institute of Demography (IIASA/VID) (KC et al. 2010; Lutz et al. 2007). The data cover 120 countries and contain information about the educational composition of the population of a given country in 5-year intervals, broken down by sex and age. Based on this, we reconstructed for each country the share of men and women born in a given 5-year period who would attain no education, primary education, secondary education, or tertiary education (neglecting possible in- and outmigration) and used this to probabilistically assign newly born agents their ultimate educational attainment (s_i) given their gender, the simulation year, and the country under consideration. Thus, as the initial agent population is replaced over the course of a simulation run, the female part of the population becomes gradually more and more educated compared to the male part of the population.

The second source is the European Community Household Panel (ECHP). The ECHP has been collected annually between 1994 and 2001 in 15 European countries and contains information about respondents' annual income and educational attainment. We used this to compute country-specific probabilities of respondents falling into one of five income quintiles during the peak income ages of 36–50 years, contingent on their gender, educational attainment, and birth year. We used this data to probabilistically assign new-born agents their earnings prospects (y_i), after assigning them their gender and their ultimate educational attainment. Hence, in the model, agents' cultural resources (represented by their education) and economic resources (represented by their earnings prospects) are correlated in a country-, gender-, and cohort-specific way.

Together, the two data sources enabled us to generate plausible opportunity structures for the 12 countries indicated above for the period 1921–2012.

6.2.1.2 Simulation Experiments and Results

Our goal was to assess how well our model is able to trace empirically observed shares of educationally hypergamous, homogamous, and hypogamous marriages in the 12 countries for which input data was available. For this, we used data from rounds 5 and 6 of the European Social Survey,[7] which were respectively collected in 2010 and 2012, and compared the shares of marriage types that the model generates with the empirical data, assuming an agent population of 250 males and 250 females. To do so, we used a two-step experimental procedure. In the first step, we calibrated the model by systematically varying some of the central model parameters to find a parameter combination that maximized the average agreement between model outcomes and the observed data across 5 of the 12 countries under consideration (Belgium, France, German, Spain, and Portugal). Of central interest were the parameters w_s, w_y, and w_a, which govern how strongly agents penalize deviations from their partner ideals in terms of education, earnings prospects, and age, respectively. Recall that the values of these parameters can differ between male and female agents. In the best-fitting parameter setting, female agents penalized deviations from the ideal income among potential partners more strongly than deviations from the ideal educational attainment. Male agents, by contrast, differentiated less between the two characteristics.[8] This is in line with

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[7]European Social Survey Rounds 5 and 6 Data (2010–2012). Norwegian Social Science Data Services, Norway—Data Archive and distributor of ESS data for ESS ERIC.

[8]The exact parameterization for female agents (f) was $w_s^f = .385$, $w_y^f = 1.201$, and $w_a^f = 10.833$; for male agents (m), the parameter values were $w_s^m = .934$, $w_y^m = 1.025$, and $w_a^m = 5.009$. The larger value of w_a^f compared to w_a^m is congruent with the observation that women tend to marry men who are on average 2–3 years older, regardless of their own age (indicating less lenient age preferences), whereas men tend to marry women who are increasingly younger than themselves,

the theoretical and empirical considerations outline above, that women tend to put relatively more emphasis on the economic resources of their partners than men. Note that we assumed that this parameterization remained stable over the course of a given simulation run, which implies that there was no change in partner preferences over time.

In the second step, we applied this parameterization to the full sample of countries and inspected how well the models' outcomes matched the country-specific empirical data. Figure 6.1 shows the results of this comparison for the birth cohorts 1941–1950, 1951–1960, 1961–1970, and 1971–1980. In almost all countries, the simulation outcomes matched the observed data well. That is, in both the empirical data and the simulation outcomes, the share of hypergamous marriages, in which the wife is *less* educated than the husband (M > F), decreased, whereas the share of hypogamous marriages, in which the wife is *more* educated than her husband (M < F), often increased. At the same time, in some countries the share of homogamous marriages, in which both partners have the same educational attainment level (M = F), increased. The difference in the observed shares of couple types and the shares that the simulation model had generated were generally small.

Figure 6.2 presents that same data as Fig. 6.1 but focuses more closely on the link between the relative educational attainment of men and women and patterns of assortative mating. The data points in the panels show the data from the different birth cohorts across countries, this time ordered according to a measure of how advantaged women in the respective cohort and country are in their educational attainment compared to men (this measure was developed by Esteve et al. 2012). A value of .5 on this measure indicates that men and women are on average similarly educated. A value of 1 indicates that any randomly selected woman is more educated than any randomly selected man and a value of 0 indicates the exact opposite. The figure illustrates that both in the observed data and the simulation outcomes, the share of hypergamous marriages decreased, whereas the share of hypogamous marriages increased, as women became relatively more educated than men.[9] Recall that in the simulation model agents' partner preferences remain stable across successive agent cohorts and that the only thing that changes is the opportunity structure in terms of educational attainment and associated earnings

but also increasingly older than the ideal of 24 years, as they grow older (indicating more lenient age preferences). This greater leniency among men may be partly owed to the fact that as they grow older themselves, it becomes more and more difficult for them to find women who are in their mid-20s and who are willing to form unions with them.

[9] As we show in Grow and Van Bavel (2015), these results are robust to changes in the preference structures that the model assumes to underlie partner search. More specifically, in a separate sensitivity analysis, we 'switched off' agents' preferences for each of the different partner characteristics one at a time, by setting the corresponding exponents to 0. For example, to assess we effect that the models' assumptions related to agents' age preferences have on model outcomes net of all other assumptions, we set $w_a^m = w_a^f = 0$ (which implies that agents would not care at all about the age of their partners), while leaving all other parameters unchanged. The fact that our main results were qualitatively not affected implies that model outcomes are not contingent on one specific assumption related to agents' partner preferences.

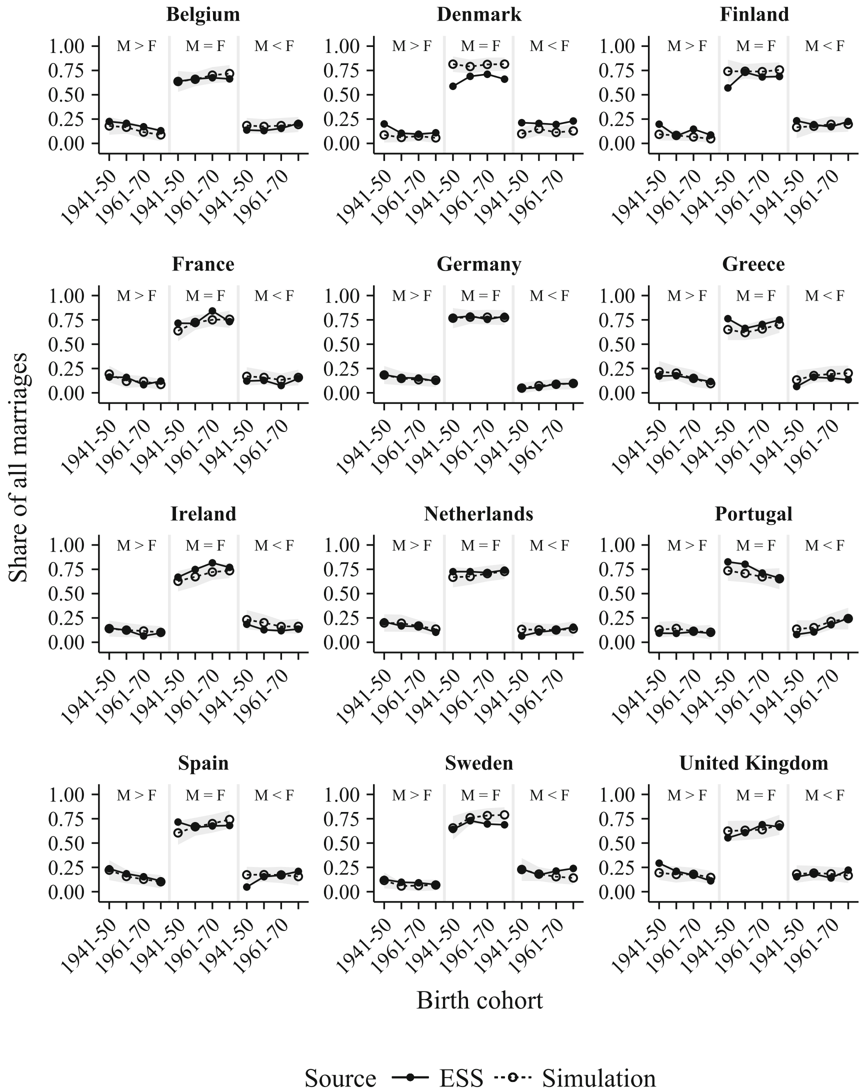

Fig. 6.1 Comparison of observed and simulated shares of couple types for four birth cohorts in 12 European countries, based on the data reported in Grow and Van Bavel (2015). The simulation outcomes show averages from 50 independent simulation runs per country and the gray area around the simulation outcomes show ±1 standard deviations of the mean simulation outcome. Hypergamous marriages are indexed as M > F, homogamous marriages as M = F, and hypogamous marriages as M < F

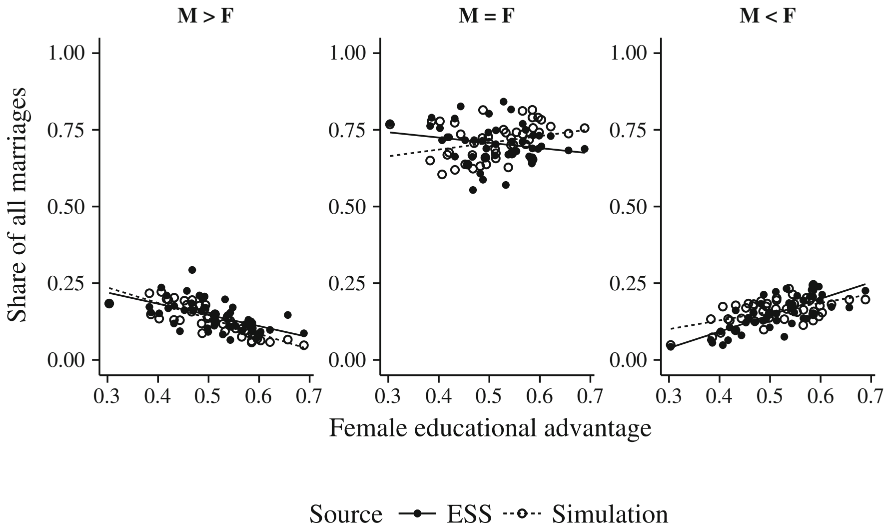

Fig. 6.2 Comparison of observed and simulated shares of couple types for four birth cohorts in 12 European countries, contingent on a measure of the female educational advantage, based on the data reported in Grow and Van Bavel (2015). The simulation outcomes show averages from 50 independent simulation runs per country. The lines are based on estimates from a simple linear regression model fitted to the shown data points. Hypergamous marriages are indexed as M > F, homogamous marriages as M = F, and hypogamous marriages as M < F

prospects among male and female agents. Hence, our results suggest that changes in preferences are not necessary to explain the association between the reversal of the gender gap in education and changes in patterns of educational assortative mating.

6.2.2 *The Cliff in Women's and Men's Relative Incomes*

Some scholars have suggested that the historical changes in women's educational attainment and economic position would lead heterosexual unions to become increasingly gender egalitarian (e.g., Jalovaara 2012; Oppenheimer 1977, 1988; Sweeney and Cancian 2004; Torr 2011). This implies that partners should become more similar in their contributions to the economic wellbeing of their families, but marked gender differences still exist (Bertrand et al. 2015; Klesment and Van Bavel 2017; Van Bavel and Klesment 2017). Figure 6.3 illustrates this for unions (marriage and unmarried cohabitation) among people age 25–45 years in four European countries (Belgium, Bulgaria, Germany, and Spain), based on pooled data from the 2007 and 2011 rounds of the cross-sectional versions of the European

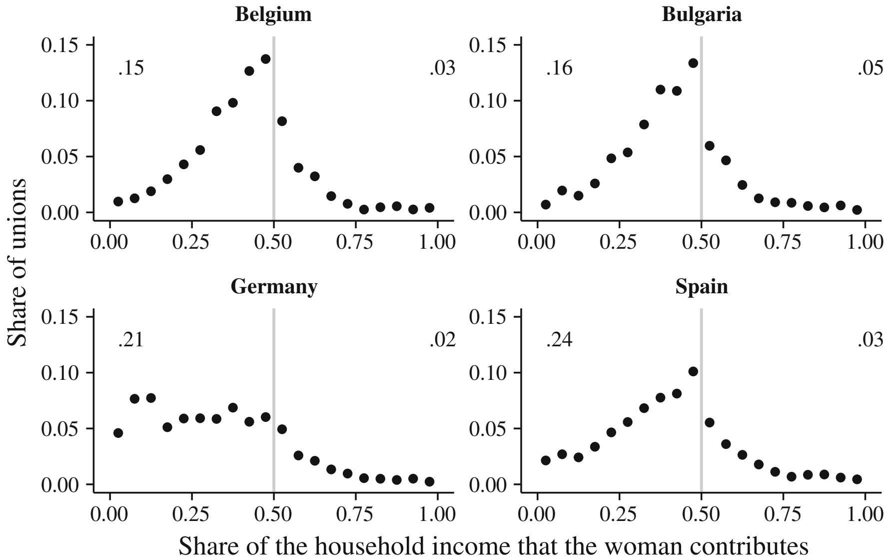

Fig. 6.3 Distributions of relative incomes within households in selected countries, based on the data reported in Grow and Van Bavel (2017). Within unions, the share that the woman contributes to the income of her household is calculated as $y_f/(y_f + y_m)$, where y_f and y_m refer to the income of the woman and the man, respectively. The grey vertical line indicates the point where the share of the household income that the woman provides is exactly 50%. The numbers in the upper left/right corner of each panel show the shares of couples in which the woman contributes nothing to/all of the household income (i.e., 0%/100%)

Union Statistics on Income and Labour Conditions (EU-SILC).[10] The distributions are right skewed and there is a discontinuity at the 50/50 demarcation line, meaning that there are comparatively many marriages where the wife earns almost as much as her husband, but there are only few marriages where she earns more. Bertrand et al. (2015) argued that such a ‘cliff’ in relative incomes at the 50/50 demarcation line points to persistent gender norms that favor the male-breadwinner/female-homemaker model, so that both men and women are aversive of a situation in which a wife out-earns her husband.

We have conducted a simulation experiment to illustrate that the observed gender differences in the relative income distribution are not necessarily indicative of traditional gender norms and preferences (Grow and Van Bavel 2017). In fact, we suggest that it is possible that such differences emerge even if gender norms are

[10] See Grow and Van Bavel (2017) for details on the sample selection. Given that in Europe unmarried cohabitation is becoming increasingly prevalent and in some countries even has attained a meaning similar to marriage (Hiekel et al. 2014), some scholars have combined both union types in their analysis of relative household incomes across Europe (Klesment and Van Bavel 2017; Van Bavel and Klesment 2017). For comparability, we also used this approach here.

completely egalitarian. The reason is that the average income of women is lower than that of men (net of the difference in relative incomes within households). This affects the opportunities for men and women to find partners who earn as much as (or even more than) they do and leads to a discontinuity at the 50/50 demarcation line to the disadvantage of women. The following dynamics lead to this outcome. Earlier marriage market research has shown that when both men and women look for partners with high-quality characteristics, competitive pressures emerge that make it likely that many matches with characteristics of similar quality form.[11] Applied to income as a relevant characteristic, this implies that there will be a tendency for people with similar incomes to form unions with each other. Yet, given that women tend to earn less than men, many men will have to 'settle' for a partner who earns less than they do. Women, by contrast, will find a larger pool of males earning more than they do because men tend to earn more, overall, than women. In the aggregate, these differences in the opportunity structures between the genders may lead to a heaping of couples close to the 50/50 point of the relative income distribution, but in many of those couples in which there is a significant difference in spouses' incomes, the man will earn more than the wife. Thus, a 'cliff' in the relative income distribution to the disadvantage of women is likely to emerge, even if there is no norm against wives earning more than their husbands.

6.2.2.1 The Models

To assess the logical consistency of our argument, we have developed a series of simulation models. Each model assumes that income is the only relevant characteristic for partner selection and they all assume the same marriage market structure in terms of men's and women's incomes (see details below). However, the models differ in their specific assumptions about partner search. Here, we focus on two of these models for illustrative purposes.

Preferences and Partner Search

The baseline model draws on a matching model that has been frequently used in economic marriage market research. The model has been developed by Gale and Shapley (1962), with the goal to provide an algorithm that can create stable matching patterns in any matching market (including marriage markets). A stable matching pattern is achieved when (1) among those who are married there is nobody who would prefer to be single over being married, and when (2) there are no two

[11] If everybody strives for partners with high-quality characteristics, people with the highest-quality characteristics will be in the best position to attract partners with high-quality characteristics. This renders it likely that men and women with the highest-quality characteristics will form unions with each other first. Once these individuals are removed from the partner market, those who occupy the highest ranks in the new quality distribution will form unions with each other next, and so on.

persons who would prefer to be married to each other over being single or over being married to their current spouse (Weiss 1997: 100).

In their model, Gale and Shapley (1962) made a number of simplifying assumptions. First, they assumed that people can assign each opposite-sex member of the marriage market a subjective utility that they expect to derive from marrying them. This makes it possible for them to rank all available alternatives. Second, Gale and Shapley (1962) assumed that the expected utility from marriage is higher than that from remaining single. Hence, all men and women prefer being married over being single, no matter the characteristics of their partner. Third, they assumed that partner selection takes the form of 'deferred selection': members of one sex decide to whom they want to propose marriage and the members of the other sex decide which proposals to accept.

More technically, if we assume that there is a set of male and female agents who are all assigned an income (y_i), and if this income is the only relevant partner selection criterion that all agents value highly (so that higher-income partners yield higher utility), the Gale and Shapley (GS) algorithm has the following iterative form (assuming that male agents propose and female agents decide which proposal to accept):

1. Each male agent who is not matched to a female agent yet proposes to the woman who ranks highest in his list of alternatives. If two or more women are tied for the highest rank, one of them is selected randomly.
2. Each female considers the proposals that she has received and:
    - 2.1 If she is not matched to a male agent yet, she keeps the proposal from the man she prefers most, so that they get matched. She rejects the proposals by all other men and is removed from the rejected men's lists of alternatives.
    - 2.2 If she is matched already, she keeps the proposal from the man she prefers most and rejects all other proposals. She then compares the utility she derives from her current partner with the utility she would derive from the proposing man. If the utility that she derives from her current partner is equal to or higher than that of the proposing man, she rejects the new proposal. However, if the utility of the proposing man is higher, the woman un-matches from her current partner and matches with the proposing man. The woman is then removed from the rejected men's lists of alternatives.

These steps are repeated until all men are matched or have exhausted their list of alternatives.[12] As Weiss (1997) highlighted, when both genders value the same characteristic in a partner, the resulting matching pattern will always look the same, no matter whether men or women get to propose. For simplicity, we only consider a situation where men get to propose.

The GS-algorithm has been popular in earlier marriage research, arguably because it is very simple and still makes it possible to generate marriage patterns that are in equilibrium. Yet, its assumptions are not very realistic. For example, the

[12]Members of the proposing sex can exhaust their list of alternatives before being matched if the sex-ratio is imbalanced so that there is a shortage of opposite-sex members.

algorithm assumes that there are no search frictions and no search costs, so that everybody has full information about all the available alternatives. In reality, most people have knowledge only about a very small subset of the marriage market and this creates a problem for them: how should they decide to whom to propose/which proposal to accept, if they do not know whether they might encounter somebody more attractive in the future? One effective way to deal with this problem is to use one's own quality as a guideline and to aim for partners who are at least of the same, or possibly higher, quality (cf. Edwards 1969; Kenrick et al. 1993; Penke et al. 2007; Sloman and Sloman 1988; Todd et al. 2013). Yet, even if a partner with higher-quality characteristics may be more attractive than a partner with similar-quality characteristics, quality differences can create feelings of inequity that put strain on the relationship and reduce relationship satisfaction. This holds in particular for the partner who has higher-quality characteristics (who is, in the terminology of social exchange theory, 'under-benefitting' from the relationship), but to some extent also for the partner who has lower-quality characteristics (who is 'over-benefitting') (Sprecher 1986, 1992). Hence, the quality of relationships among partners of different qualities is likely to suffer, thereby increasing the risk of union dissolution and repartnering, to the extent that attractive alternatives are available.

It is therefore more plausible to assume that people have incomplete information about the composition of the marriage market and that they strive for similar-quality partners, but generally prefer higher quality over lower quality. We have implemented these assumptions by modifying the GS-algorithm in the following way. First, we assume that agents engage in a sequential search processes, so that in each iteration of the simulation members of one sex can meet one randomly selected member of the opposite sex. In each meeting, both agents need to decide whether they want to start a relationship with each other and leave possible current partners for this. Second, we assume that agents who are not matched to somebody else yet always search for a partner and thus will always meet somebody who is also looking for a partner (if there are opposite-sex members who are also looking for a partner). Yet, the probability that agents search for a partner is reduced when they already have a partner, contingent on whether they are under- or over-benefiting from their relationship. More specifically, we assume that agents who have a partner whose income is lower than their own are more likely to engage in partner search than agents who have a partner with similar or higher income. We set these probabilities to $\alpha = .5$ and $\beta = .2$, respectively. Here, the fact that $\alpha > \beta$ reflects the notion that people who are under-benefitting from their relationship are likely to be less satisfied with it than people who are over-befitting and therefore may be more inclined to look for alternatives.

More technically, the modified GS-algorithm looks as follows:

1. Determine for all male and female agents whether they are actively looking for a partner. For agents who are not matched yet, this is always the case. For agents who are already matched and whose partner earns less than they do, there is a 50% chance that this is the case ($\alpha = .5$); for agents who have a partner who earns more than, or as much as, they do, there is a 20% chance that this is the case ($\beta = .2$).

2. Randomly pair each male agent who is looking for a partner with exactly one female agent who is also looking for a partner (some men or women might not be paired if the numbers of men and women who are looking for a partner are imbalanced). Within each such pairing, both agents determine whether they want to signal to the other agent that they want to start a relationship. These decisions are based on the following rules:
   2.1 If a given agent is not matched to somebody else yet, the agent always indicates that he/she is willing to start a relationship with the agent he/she has been paired with.
   2.2 If a given agent is already matched to somebody else, the agent signals that he/she is willing to start a relationship with the agent he/she has been paired with, if the income of the alternative is higher than that of his/her current partner.
3. For all pairs in which both agents have indicated that they are willing to form a relationship, break relationships with possible current partners and let them start a relationship with each other.

Steps one to three are repeated 20 times. We selected this number of iterations for two reasons. One the one hand, this simulation period is long enough for agents to engage in sequential partner search, so that they can compare a number of alternatives. On the other hand, this period is short enough so that no agent will encounter every opposite-sex member, meaning that they will have only incomplete information about the marriage market.

Opportunity Structures

We assumed a marriage market that consists of a fixed population of 1000 male and 1000 female agents. We assigned these agents their annual income (y_i) at the beginning of a given simulation run. This happened probabilistically, based on the country- and gender-specific income distributions among men and women in the EU-SILC data introduced above. Data was available for 27 countries, which we treated as separate national marriage markets.

6.2.2.2 Simulation Experiments and Results

The goal of our simulation experiments was to assess how well the relative income distributions that the GS-algorithm and the modified GS-algorithm generate match those observed in the EU-SILC data. Given that agents were assigned their income randomly, we conducted 25 independent simulation runs per algorithm and country and averaged outcomes over these runs.

Figure 6.4 illustrates the outcomes of the two models and compares them with the empirically observed patterns of relative income for the four countries shown

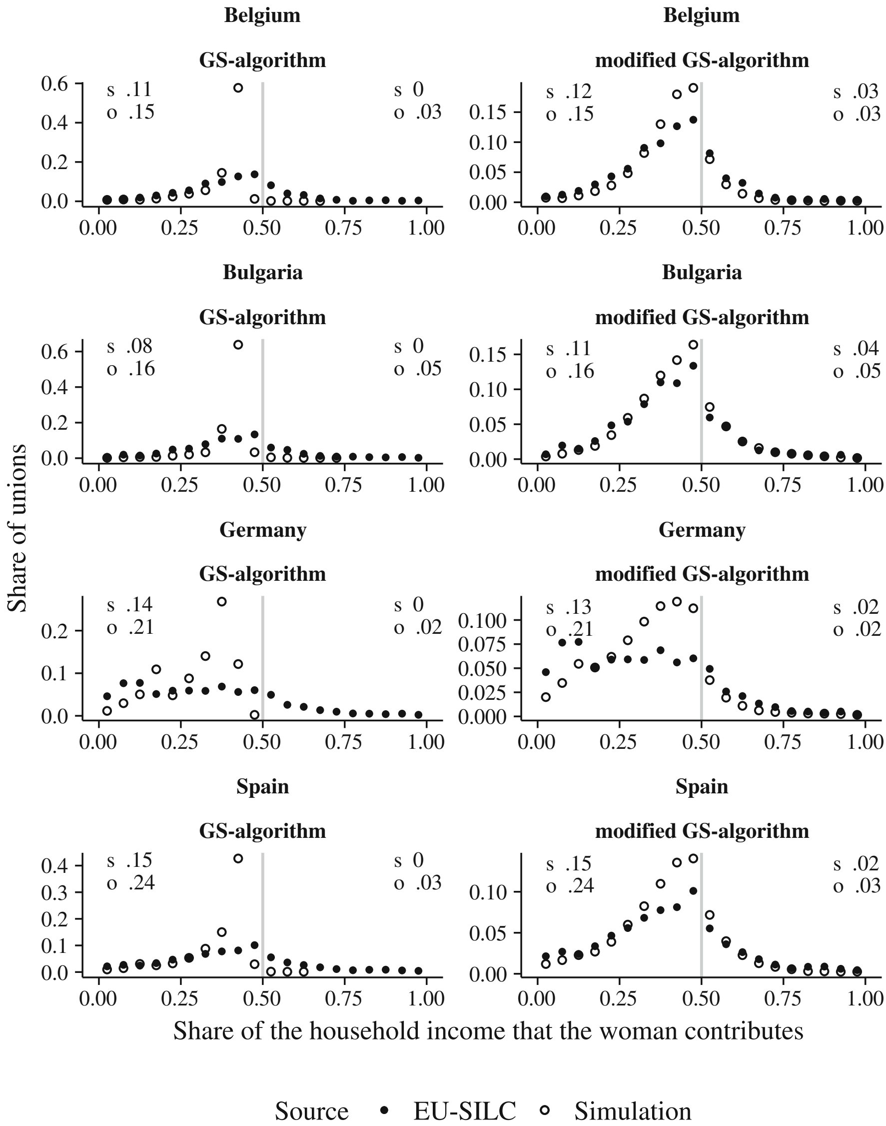

Fig. 6.4 Comparison of observed and simulated relative income distributions in selected countries, based on the data reported in Grow and Van Bavel (2017). Within unions, the share that the woman contributes to the income of her household is calculated as $y_f/(y_f + y_m)$, where y_f and y_m refer to the income of the woman and the man, respectively. The grey vertical line indicates the point where the share of the household income that the woman provides is exactly 50%. The numbers in the upper left/right corner of each panel show the shares of couples in which the woman contributes nothing to/all of the household income (i.e., 0%/100%), as obtained from the simulations ('s') and observed in the empirical data ('o'). The scaling of the y-axis varies across the graphs for ease of comparison

in Fig. 6.3. How well do the outcomes of the simulation models match these empirical distributions? The left column in Fig. 6.4 shows for each country the corresponding outcomes based on the GS-algorithm. Surprisingly, the comparison suggests that the cliff in the income distribution that this algorithm creates is much larger than observed empirically. That is, the share of couples typically increases steeply from the point where the woman earns nothing to the point where she provides about 40% of the household income. After this, there is sharp drop in the distribution and there are almost no unions in which the woman provides more than the male partner. The right column of Fig. 6.4 shows the results of the modified GS-algorithm. Compared to the outcome of the original GS-algorithm, the outcomes of its modified version are much closer to the empirical patterns. That is, similar to the observed distributions of relative income, the distributions that the simulation model generates tend to peak close to the 50/50 point, much of the mass of the distributions is on the left-hand side of this point, and there is a strong discontinuity immediately after it.

Recall that in the modified GS-algorithm, we assumed that agents who have a partner who earns less than they do are more likely to look for an alternative than agents whose partner earns as much as or more than they do ($\alpha > \beta$). In Fig. 6.5, we show the results of a simulation experiment that assesses how sensitive our results are to this assumption. For this, we varied α and β orthogonally to each other in the steps .2, .5, and .8. The results are very similar across countries and we therefore only show the outcomes for Belgium. Note that for ease of comparison and readability, we have added lines to the graphs and omitted information about the shares of couples where the female agent contributes 0% or 100% to the household income. The results suggest that as agents who have a lower-income partner become more likely to look for an alternative (i.e., as α increases), the shares of couples that are close to the 50/50 demarcation line tend to increase. At the same time, a cliff tends to emerge, in particular when the inclination to look for an alternative among agents who have a similar- or higher-income partner is relatively lower (i.e., when β is smaller than α).

Taken together, our results suggest that given the earnings of men and women, a cliff in the relative income distribution can emerge even if people's partner preferences are completely gender egalitarian, so that they do not evaluate a situation in which a wife earns more than her husband any differently from a situation in which the husband earns more. Yet, it is important to note that we do not claim that norms that favor differentiated roles of men and women within their families do not exist in some parts of the population in at least some countries. For example, the empirical patterns displayed in Fig. 6.3 show that in Germany there are many more families in which the wife contributes less than 25% of the household income, while at the same time there are fewer families in which the wife provides about as much as the husband than there are in the other countries. One factor that may contribute to this is the fact that in Germany the joint family income is taxed (rather than individual income), which creates disincentives for the partner with the lower earning potential to participate full-time in the labor market. At the same time, there is a comparatively high social acceptance of mothers who stay at home to care

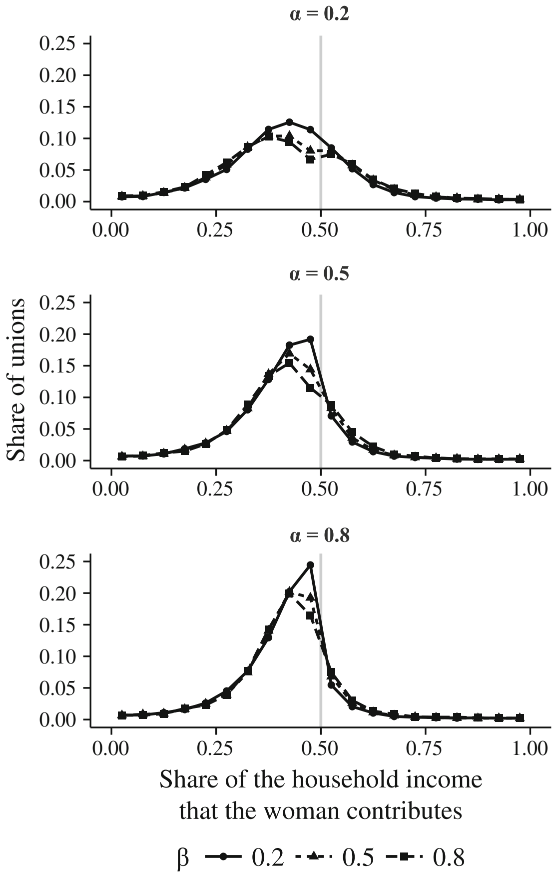

Fig. 6.5 Sensitivity analysis of the modified GS-algorithm for Belgium. Within unions, the share that the woman contributes to the income of her household is calculated as $y_f/(y_f + y_m)$, where y_f and y_m refer to the income of the woman and the man, respectively. The grey vertical line indicates the point where the share of the household income that the woman provides is exactly 50%. The parameter α defines the probability that agents whose partner earns less than they do will look for an alternative; the parameter β defines the probability that agents whose partner earns as much as or more than they do will look for an alternative

for their children, especially in West Germany. Together, this creates a tendency towards a "one and a half earner model, strongly based on women's part-time employment" (Aboim 2010, p. 181). Nevertheless, our results suggest that a cliff in relative incomes in households is likely to persist even if such norms ceased to exist, as long as women earn less than men.

6.2.3 *The Gender-Gap Reversal in Educational Attainment and Divorce*

Changes in the relative educational attainment of men and women were not only linked to changes in patterns of union formation, but also to changes in union dissolution. In the past, hypogamous marriages were more likely to end in divorce than hypergamous marriages, but Schwartz and Han (2014) reported than in recent marriage cohorts in the US both marriage types were equally likely to dissolve. Schwartz and Han (2014) suggested that these changes in divorce patterns might be indicative of cultural and normative change. As discussed above, in times in which the male-breadwinner/female-homemaker model was dominant, both men and women tended to be aversive of a situation in which a wife has higher socioeconomic status than her husband. Hence, being married to a more educated woman might have posed a threat to a man's male gender identity and this may have created strains within hypogamous marriages, ultimately leading to an increased divorce risk compared to more traditional marriages. Yet, as hypogamy became more widespread, and as cultural norms became generally more gender egalitarian, hypogamous marriages may have come to be perceived less non-normative. This, in turn, may have reduced the risk that such marriages dissolve.

We have explored an alternative mechanism that may also lead to a convergence in the divorce risks of hypergamous and hypogamous marriages, without the need to assume cultural and normative change (Grow et al. 2017). The proposed mechanism draws on the macrostructural-opportunity perspective on divorce (South et al. 2001). In line with the social exchange perspective on marriage, the macrostructural-opportunity perspective assumes that individuals remain on the marriage market after marriage (even if only tentatively) and therefore are open for repartnering when they encounter marital alternatives that are more attractive than their current spouse. The probability that men and women encounter such alternatives is affected by the sex ratio on the marriage market. If men are more numerous than women, women will have increased chances of encountering attractive marital alternatives and therefore should have an increased probability of leaving their partner; the same holds for men if women are more numerous. Hence, the divorce rate should increase if the sex ratio is imbalanced, and empirical research suggests that this indeed is the case (e.g., South and Lloyd 1992, 1995). In the mechanism that we propose, we specify the sex ratio by the educational attainment of the available men and women on the marriage market. As indicated above, education is an important factor in partner selection and the gender-gap reversal in educational attainment implies a declining ratio of highly educated men to highly educated women. If we assume that highly educated men and women prefer similar educated partners over lower educated ones (everything else being the same), it becomes apparent that their repartnering opportunities have changed over the last decades. In particular, highly educated women who are married to a less educated man have become *less likely* to meet alternatives who are more educated than their partner, meaning that their repartnering opportunities have worsened. By contrast, highly educated men who are married to lower educated women have become *more likely* to meet a more educated alternative, meaning that their repartnering opportunities have improved. This may have contributed to an increase in the divorce risk of hypergamous marriages and decrease in the divorce risk of hypogamous marriages.

Albeit the mechanism that we describe might appear plausible at the surface, the behavior and decision processes that it entails are complex and might lead to unexpected outcomes. The reason is that marriage and divorce decisions are interdependent. The probability that two individuals form a union with each other is affected by the structure of the marriage market, but at the moment they actually marry, they slightly alter the availability of alternatives for others. Conversely, the availability of alternatives may affect divorce decisions, but every time two people get divorced, they also alter the availability of alternatives for others. To deal with this complexity, we relied on agent-based modeling to assess the logical consistency of our argument.

6.2.3.1 The Model

The model that we have developed to study the link between the reversal of the gender gap in educational attainment and patterns of assortative mating (Sect. 6.2.1 above) is highly suitable for assessing our argument related to divorce, for two reasons. First, the model implements the effect that the reversal of the gender gap in education has on the opportunity structure on the marriage market, which is the first key element of our argument. Second, the model assumes that agents remain on the marriage market even after marriage and therefore may divorce from their partner if they find an alternative that is more attractive. This assumption is congruent with the macrostructural-opportunity perspective, which is a second key element of our argument. Hence, it was possible to use this model for the study of divorce, with only minor modifications. For example, the original model focused on individuals and their marital status at a given point in time; for the study of divorce, we adjusted the model so that it also tracked individual marriages and recorded the simulation year in which they formed or dissolved. We also included country-, period-, and gender-specific data on mortality and fertility rates to increase the realism of the opportunity structures in which agents looked for potential partners. The reason for this was that especially at higher ages people (and in particular women) have an increased probability of becoming widow(er)s, which alters the opportunity structures in higher-age groups.

6.2.3.2 Simulation Experiments and Results

To assess our argument, we conducted a simulation experiment in which we simulated partner search and re-partnering decisions in the same 12 countries as in Grow and Van Bavel (2015), using virtually the same model parameterization. Following the empirical work of Schwartz and Han (2014), we focused on the probability that marriages that had formed between 1950 and 2004 would end in divorce. For this, we extended the simulation period from 1921–2012 to 1921–2064, to avoid that censoring in later marriage cohorts might bias our results.

Our particular interest was in the relative divorce risk of hypogamous marriages compared to hypergamous marriages. Our argument suggests that the divorce risk among hypergamous marriages may increase, and the risk among hypogamous marriages decrease, even if people's partner preferences and the gender norms that surround their decisions would remain stable over time. Figure 6.6 provides a first

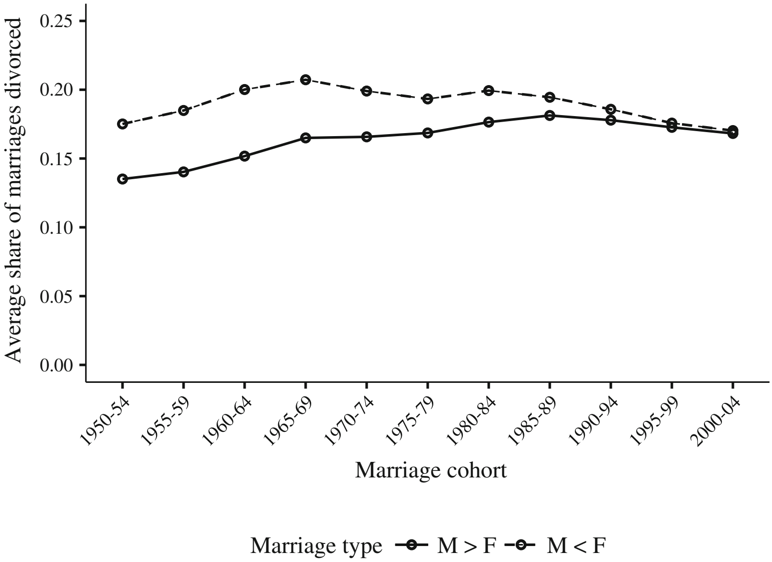

Fig. 6.6 Shares of hypergamous (M > F) and hypogamous marriages (M < F) that ended in divorce by marriage cohort, simulated for 12 European countries, based on the data reported in Grow et al. (2017). The outcomes are averages from 1000 independent simulation runs per country

assessment of this, by showing the average divorce rate of the two marriage types across marriage cohorts, based on the pooled outcomes from the 12 countries in our simulation experiment. The figure shows that in the marriage cohort 1950–1954, the divorce rate among hypogamous marriages was higher than among hypergamous marriages. However, these rates converged over subsequent cohorts and by the cohort 2000–2004 the two marriage types had a similar divorce rate.

In Fig. 6.7, we assess more closely the extent to which this convergence is due to changes in the opportunity structure in terms of the relative educational attainment of men and women. While Grow and Van Bavel (2015) were interested in union formation, we are interested in union dissolution here, so we aimed to assess the opportunity structures in which divorces took place. For this, we calculated the average time until divorce in the simulation, which was about 3–4 simulation years, and calculated for each marriage cohort the measure of the female educational advantage after this period of time (e.g., for the marriage cohort 1950–1954, we calculated the female educational advantage for the year 1955). Figure 6.7 relates this measure to the ratio of the shares of hypogamous marriages that ended in divorce over the shares of hypergamous marriages that ended in divorce in the respective marriage cohorts in a given country in our simulation model. On this measure, values larger than one imply that hypogamous marriages were *more* likely to dissolve than hypergamous marriages and values smaller than one imply that hypogamous marriages were *less* likely to dissolve than hypergamous marriages. The figure shows that as the female educational advantage increased, the divorce risk

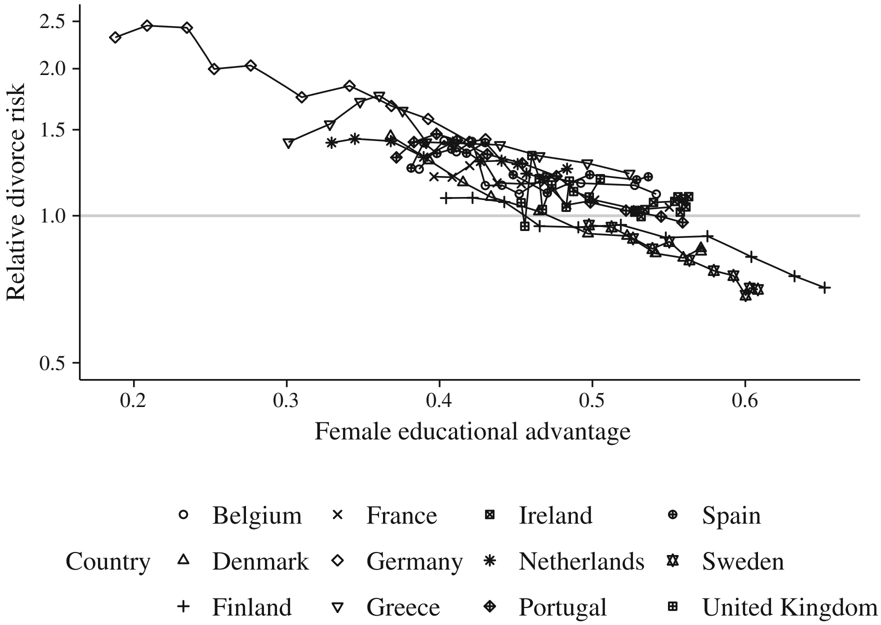

Fig. 6.7 Relative risk that hypogamous marriages end in divorce compared to hypogamous marriages, contingent on a measure of female educational advantage, simulated for 12 European countries and 11 marriage cohorts, based on the data reported in Grow et al. (2017). The y-axis shows the ratio of the share of hypogamous marriages that had ended in divorce over the share of hypergamous marriages that ended in divorce on a log scale. Each line represents one country, with each point representing one five-year marriage cohort, starting with the cohort 1950–1954 and ending with the cohort 2000–2004. The results are based on averages from 1000 independent simulation runs per country

of hypogamous marriages decreased compared to that of hypergamous marriages. In fact, as women became on average more educated than men, the relative divorce risks even inverted, so that hypergamous marriages became more likely to end in divorce than hypogamous marriages. Hence, our simulation results suggest that we can explain the convergence in the divorce risks of hypogamous and hypergamous marriages over time without needing to invoke normative changes.

6.2.4 General Discussion

Demographers have since long conceptualized changes in attitudes and changes in family patterns as reciprocally linked (e.g., Axinn and Thornton 1993; Bumpass 1990): when attitudes change, family behavior tends to follow, but attitudes also change in response to structural and economic pressures that lead to new family behavior. Concerning the dramatic changes in family life that have taken place in Western countries since the 1960s, it is difficult to determine in which of these domains the triggering events were located. For example, proponents of the theory of the second demographic transition (Lesthaeghe 2014) suggest that many of the observed changes in family behavior were 'kick-started' by exogenous changes in attitudes. These attitudinal changes encompassed a stronger desire for individual autonomy and emancipation, an increasing rejection of institutional controls and authority, and a larger emphasis of individuals' expressive needs (Surkyn and Lesthaeghe 2004). Together, these changes altered people's family behavior, leading to a decrease in marriage and fertility, and an increase in new living arrangements that was partially based on the rejection of the legitimacy of the male-breadwinner/female-homemaker family model and the accompanying gendered division of labor. By contrast, Ruggles (2015, p. 1807) suggested that "[a]ttitudes are ordinarily a barrier to change, not a cause of change: there must be a source of exogenous pressure for people to reject the values with which they were raised". In his view, the observed changes in family behavior were 'kick-started' by an economic revolution. In this revolution, the traditional male-breadwinner/female-homemaker model initially became possible due to an increase in the availability of well-paying wage-jobs for men in the late nineteenth and early twentieth centuries, which made it easier for men to form and support independent families. Subsequent increases in the demand for labor led to an increase in the share of women in the labor force and an increase in the number of dual-earner families. As women became increasingly active outside the home and contributed to the economic well-being of their families, gender and family attitudes adjusted and became more egalitarian, thereby facilitating further change.

The three simulation studies that we have presented here do not enable us to advocate between these two views on the causes of demographic change. However, they highlight that earlier research may have over-emphasized the importance of attitudes and preferences for explaining observed changes in family behavior. As indicated above, the increase in the relative number of educationally hypogamous unions has been interpreted as possibly resulting from changing gender and family norms that put increasing emphasis on equality and the possibility of self-realization for the members of both genders. Yet, the results of the simulation studies that we have presented here suggest that hypogamous unions may have become more prevalent *even if the attitudes and preferences that underlie partner choice would have remained unchanged*. Similarly, the observed convergence in the divorce risks of hypogamous and hypergamous unions has been attributed to a loosening of family norms that viewed hypogamy more negatively than other union forms. As we have shown, such a convergence in divorce risks may have occurred *even in the absence of any change from a negative to a neutral evaluation of hypogamy compared to other union forms at the societal level*. By contrast, the persistence of the 'cliff' in relative incomes within households has been attributed to persistent gender norms that favor the male-breadwinner/female-homemaker model. The results that we have presented here suggest that the cliff may persist *even if the attitudes and preferences that underlie partner choice would become completely gender egalitarian*. This should not be interpreted as implying that attitudinal change did not occur, or that changes in attitudes were secondary to structural and economic pressures in shaping family behavior. Rather, our results highlight that future research should consider the possibility of a recursive link between attitudes and family behavior in the areas that we have explored more carefully and avoid committing an ecological fallacy by inferring micro-level attitudes and preferences (and changes therein over time) from macro-level family patterns.

Our results illustrate how the opportunities and constraints that people face on the marriage market can facilitate or hamper family change. What do these insights tell us about the possible future of family behavior? Our results suggest that any further convergence of men's and women's roles within their families is unlikely to be rooted in a development towards more egalitarian family norms and partner preferences alone. As we have shown, even if people's partner preferences would be completely gender egalitarian, it would be likely that men continue to provide the largest part of the family income, as long as they earn more than women on average. Thus, as Goldin (2014) suggested, the 'last chapter of the grand gender convergence' will require also institutional changes aimed at reducing the gender pay gap, as this is likely to create the structural conditions that are necessary to attain more equality within families.

6.3 Recommendations and Conclusion

Advocates of ABC modeling have highlighted the many benefits that the method yields for research in the social sciences (e.g., Epstein 2008). As we have illustrated in this chapter, one of the central benefits that ABC modeling yields for family demography is that it provides researchers with a flexible computational laboratory in which the complex implications of alternative assumptions and mechanisms can be studied with precision. While ABC modeling can aid our understanding of familial processes, it is important to keep in mind that the fact that a given simulation model can generate a given macro-level phenomenon does not prove that the mechanisms that the model implements represent the 'true' explanation of the phenomenon, as we have highlighted above. Related to this is the risk of overfitting a simulation model to a phenomenon of interest. Simulation models often contain many parameters that can be set in different ways. As the number of parameters increases, so does the probability that the model can fit any macro-level pattern (Epstein and Forber 2013). This problem is not unique to ABC modeling, but is a feature of modeling in general (Van Bavel and Grow 2016).[13] There are several strategies to address this problem. First, the assumptions on which the micro level of the model is based should be derived as much as possible from existing

[13] For example, in linear regression models, the explained variance in the outcome tends to increase with the number of variables that are included in the model, even if none of these variables are causally related to the outcome.

theoretical and empirical research. Sometimes this makes it possible to not only narrow down the possible behaviors that agents might engage in, but to also assign specific values to the different parameters of a model. For example, in Grow and Van Bavel (2015), we used insights from earlier research to constrain the range of possible values for some of the model's parameters. Still, often it will not be possible to constrain certain parameters in this way, simply because of a lack of empirical data. One way to address this issue is to partition the data to which the model is to be applied into a training sample (to which the model is fitted and based on which its free parameters are calibrated) and a validation sample (against which the model is validated). In Grow and Van Bavel (2015), we did this by first fitting the model to a subset of five countries, and subsequently applying the resulting parameterization to the remaining countries. This approach reduces the probability that the parameter selection is overly affected by the idiosyncrasies of one specific country. Another–complementary–approach is pattern-oriented modeling (Grimm et al. 2005). With this approach, the model is first fitted to the patterns of interest and then additional model outcomes are compared with other patterns that were not in the focus of the fitting exercise. For example, a model that focuses on patterns of assortative mating should also generate realistic patterns of age-at-first-marriage, a realistic marriage rate, plausible age differences within couples, etc. The more of these additional patterns the model fits, the higher its plausibility.

Fitting a model to observed data should be part of a systematic sensitivity analysis, in which the relation between model parameters and model outcomes is explored. For this, researchers can draw on the theory of the design of experiments (DOE), which provides guidelines for effective and efficient experimental designs. 'Effective' means here that the experiment explores the different possible values of the model's parameters in a way that provides comprehensive insights into the model's behavior. 'Efficient' means here that the number of simulation runs that are needed for this are kept to a minimum, to reduce computation time. Kleijnen (2008) provides a comprehensive overview of common approaches used in DOE and Grow (2016), Bijak and colleagues (2013) and Hilton and Bijak (2016) illustrate how these and additional approaches can be used for sensitivity analysis in demographic applications. One specific issue in this process is the question of proper scaling. An agent population should be large enough to reflect empirical variation in population characteristics with sufficient detail, but unnecessarily large agent populations can slow down the simulation process considerably. One way to address this issue is to explore how sensitive model outcomes are to changes in population size. In exploratory simulation experiments that preceded the main experiments reported in Grow and Van Bavel (2015), we determined that a population size of 250 male and 250 female agents was large enough to produce stable results. Yet, as Grow et al. (2017, p. S20) indicate, the study of divorce required larger populations. The reason is that while most of the agents experienced marriage at some point of their lives, only about 13% of those agents who got married experienced divorce. Thus, to ensure that there was a sufficient number of divorces in the agent population for the analyses, Grow et al. increased the number of agents in the initial population to 1000 males and 1000 females. Similarly, in the model that we describe in Grow and Van Bavel (2017), we also opted for larger agent populations of 1000 males and 1000 females, to ensure that the artificial populations reflected variation in the detailed income data that we used for initializing the model with sufficient detail.

In developing agent-based models, it can be tempting to design a model as closely as possible after the social system under consideration. Yet, it is often not advisable to do so. The reason is that with this approach the number of parameters (and the number of assumptions that need to be made) often increases drastically and this can make it difficult to understand the behavior of the model and may lead to overfitting (as described above). This ultimately undermines the benefits that ABC modeling can provide for our understanding of the behavior of the social system under consideration. A common recommendation to avoid this problem is to start with a model that is as simple and possible and only contains assumptions and aspects that are thought to be central to the theory or mechanism under consideration (e.g., Billari et al. 2003). Starting from this foundation, the complexity of the model can then be gradually increased, if necessary. Indeed, there are several ways in which future research could increase the complexity of the simulation models that we have introduced above, and this may lead to intriguing new insights. For example, as we highlight in Grow et al. (2017, pp. S30–S31), our model of divorce only considers union dissolution because of repartnering, because this is in the focus of the macro-structural opportunity theory which had inspired our simulation experiments. However, unions can dissolve for many additional reasons (see Amato and Previti 2003 for an overview of common divroce reasons). We do not expect that implementing such additional sources of divorce will fundamentally alter the outcome of the mechanism that we sought to explore, unless there are systematic differences between educationally hyper-, homo-, and hypogamous marriages in their propensity to dissolve in the absence of marital alternatives. Future research may introduce this possibility into the model and explore its consequences for the robustness of the mechanism that we have described.

In line with the above, Courgeau et al. (2016) suggested that the most promising approach to using ABC modeling in demographic research is based on an iterative process, in which the strengths of this method are combined with the strengths of the other methods in the demographers' tool box. This process starts with using existing empirical research to inform an initial simulation model. The insights that this model generates can then be used to guide future data collection and analyses which, in turn, can be used to refine the model (cf. also Van Bavel and Grow 2016).

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