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The reversal of the gender gap in education and relative divorce risks: A matter of alternatives?

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Short title

The gender gap in education and divorce

Abstract

Recent empirical evidence suggests that the reversal of the gender gap in education was associated with changes in relative divorce risks: marriages in which the wife was more educated than the husband used to have a higher divorce risk than when the husband was more educated, but this difference disappeared. One interpretation in the literature holds that this might be a consequence of cultural change, involving increasing social acceptance of hypogamy. We propose an alternative mechanism that need not presuppose cultural change: the gender-gap reversal in education has changed the availability of marital alternatives for highly educated women and men. This may have lowered the likelihood that women leave husbands with less education and stimulated men to leave less educated spouses. We apply an agent-based model to 12 European national marriage markets to illustrate that this mechanism is sufficient to explain the convergence in divorce risks.

Keywords

Divorce, Repartnering, Marriage Market, Education, Sex Ratio, Gender, Assortative Mating, Agent-Based Computational Modelling

Introduction

Over the last decades, Europe, North America, and many other parts of the world have experienced dramatic changes in the educational attainment of women relatively to that of men. Until the 1970s, university education was mostly a male domain, but female participation steadily increased. Since about the 1990s, women excel men in terms of participation and success in higher education (Schofer and Meyer 2005). One consequence of this reversal is that longstanding patterns of educational assortative mating have changed. In most couples, wife and husband have a similar level of educational attainment (homogamy). But, in the past, if there was a difference in educational attainment, the wife tended to be less educated than the husband (hypergamy). Today, if there is a difference, the wife tends to be more educated than the husband (hypogamy) (Esteve et al. 2012; De Hauw et al. 2015; Grow and Van Bavel 2015). The reversal of the gender gap in education is likely to also affect many other aspects of family life (Van Bavel 2012). In this paper, we explore how changing patterns of educational attainment among men and women may affect divorce risks, in particular among marriages in which spouses differ in educational attainment.

Earlier studies have shown that marriages in which the wife is more educated than the husband were less stable, giving rise to the concern that the increasing prevalence of hypogamous unions might lead to higher divorce rates (see Schwartz and Han 2014 for a review). However, Schwartz and Han (2014) showed that in the United States in recent cohorts hypogamous unions no longer exhibit a higher divorce risk than other union types. The authors suggested that this convergence might be the result of changing norms and family values. Hypogamous marriages used to be uncommon and violated the norm that a husband should have a higher socioeconomic status than his wife, in line with the male breadwinner family model. In recent years, as women's educational attainment increased and their market participation continued to expand, family values have become more egalitarian. This may have rendered hypogamous marriages less non-normative and might have reduced the threat that a more educated spouse poses to a man's gender identity.

We propose a different mechanism that may also lead to a convergence in the divorce risks of hypogamous and hypergamous marriages, without the need to assume that norms and family values change. Our argument draws on the macrostructural-opportunity perspective on divorce, that highlights the availability of spousal alternatives as an important factor in divorce decisions (South et al. 2001). Research from this perspective builds on two central assumptions. First, individuals tentatively remain on the marriage market even after marriage and potentially leave their partner when they encounter more attractive marital alternatives. Second, the likelihood that people will encounter marital alternatives increases if there is an oversupply of opposite-sex members on the marriage market. Together these assumptions imply that the divorce rate increases if the sex ratio on the marriage market is imbalanced (South and Lloyd 1992, 1995; South 1995; South et al. 2001).

We investigate the implications of this mechanism when the sex ratio is specified by the educational attainment of potential mates. Research has consistently shown that educational attainment is an important dimension in mate selection (Kalmijn 1998; Lewis and Oppenheimer 2000; Hitsch et al. 2010; Skopek, Schulz, and Blossfeld 2011), and the reversal of the gender gap in education implies a declining ratio of highly educated men to highly educated women. Combined with the assumptions of the macrostructural-opportunity perspective, this can be expected to have implications for divorce risks. The likelihood that a highly educated woman married to a less educated man encounters an alternative with more education than her partner has substantially decreased over the last decades. Conversely, the likelihood that a highly educated man married to a less educated woman will encounter a more educated alternative has increased. As a consequence, the divorce risk of hypogamous marriages might have decreased, whereas the divorce risk of hypergamous marriages might have increased.

The foregoing reasoning appears intuitive, but the link between the marriage market and divorce patterns is more complex. One factor is that people's divorce decisions are highly interdependent (Chiappori and Weiss 2006). For example, individuals who are single or divorced are more easily available for repartnering than individuals who are married (cf. Stauder 2006). Thus, if the marriage market contains many married individuals, people will be less likely to meet alternatives who are easily available for repartnering than when fewer people are married. To deal with such complexities, we make use of agent-based computational modelling and draw on the model of educational assortative mating developed by Grow and Van Bavel (2015). This model has been developed to study the link between the reversal of the gender gap in education and assortative mating. Whereas the model has not been developed with a focus on union stability, its assumptions about mate search and divorce are congruent with the assumptions that underlie our argument. This makes the model particularly suitable for our purposes.

We explore the proposed mechanism with data on the marriage market structure of 12 European countries for marriages formed between 1950–2004. For simplicity, we limit our analysis to heterosexual marriage and do not distinguish non-marital cohabitation from this. We are aware that cohabitation has been on the rise in recent years and that the stability of such unions is lower than that of marriages (Sobotka and Toulemon 2008; Schnor 2015). We assume, however, that the proposed mechanism applies to both marriages and cohabitations.

In what follows, we first present the basic assumptions of the macrostructural-opportunity perspective and discuss the role that educational attainment plays in mate selection. Subsequently, we describe the model and the design of our computational experiments.[1] We close with a discussion of our results and their implications for future research. Our simulation experiments suggest that the gender-gap reversal might indeed lead to a convergence in the divorce risks of hypogamous and hypergamous marriages, by affecting the availability of attractive marital alternatives. This convergence occurs even if we assume that the values and norms that surround family formation do not change. Yet, as discussed in the conclusion, the proposed mechanism can exist alongside mechanisms based on normative change and might even reinforce them.

The availability of marital alternatives and divorce

The assumption that marriages might dissolve when at least one partner encounters a more attractive alternative is consistent with the concept of marital bargains. This concept holds that "[j]ust as trading relationships dissolve when one of the parties locates a more profitable trading partner, many marriages dissolve when one of the spouses locates a more attractive marital partner" (South et al. 2001, p. 744). Yet, individuals do not always leave their partner when they meet a more attractive alternative. One important reason for this is the existence of partnership-specific investments, such as common children and shared house ownership (Stauder 2006). These tend to increase the commitment to the current partner. However, even if such 'barriers' to separation exist, there is at least some chance that people will leave their spouse when they meet a more attractive alternative (Farber 1964; Levinger 1976; Becker et al. 1977).

If there are potentially more appealing alternatives on the marriage market, why would people marry a less attractive partner in the first place? Theories of marital search processes explain this with the uncertainty that partner search involves (England and Farkas 1986; Oppenheimer 1988). Men and women have specific preferences for the characteristics of their mates but they cannot know exactly if and when they will find the ideal partner. The less favourable the marriage market conditions are, the more difficult it becomes to find an attractive partner. The more time people have already invested in the search process, the riskier it becomes to pass up on potential spouses, given that the pool of available alternatives shrinks and the own market value decreases with age. This is particularly the case among women, given that they are judged more by youthful appearance than men (England and McClintock 2009). In response to this increasing risk, individuals tend to lower their aspirations and become willing to accept partners who are 'less than perfect' as they grow older (Lichter 1990). Even if marriage market conditions are favourable, people might still partner with a less than perfect mate, if they invest little in mate search and settle for a partner early (South 1995; Todd and Miller 1999).

The macrostructural-opportunity perspective highlights that the real or perceived likelihood that people will encounter attractive marital alternatives is partly determined by the numerical availability of opposite-sex members (South and Lloyd 1995). In a marriage market in which women outnumber men, men face a large pool of potential spouses and should therefore be more likely to encounter a more attractive alternative than when there is gender parity. As a consequence, they should be more likely to opt for divorce. Conversely, when men outnumber women, women face more favourable remarriage prospects and therefore should be more likely to opt for divorce. This should hold unless there are strong normative pressures or legal structures that prevent men or women from divorcing their spouses (cf. Guttentag and Secord 1983; South and Lloyd 1995).

Empirical evidence for the Western context largely supports the hypothesis of the macrostructural-opportunity perspective (Udry 1981; White and Booth 1991; South and Lloyd 1992, 1995; South 1995; South et al. 2001; Rapp et al. 2015). For example, Udry (1981) showed that among husbands and wives, already the mere perception that there are many attractive alternatives (assessed through survey items) is associated with an increase in divorce risks. Using the sex ratio in the local marriage market as a more objective measure of mate availability, South (1995) demonstrated that an oversupply of either sex is associated with an increase in divorce risks. Similarly, South et al. (2001) calculated sex ratios at the regional level and found a positive effect of an oversupply of either men or women on divorce risks. One exception is a study by Lyngstad (2011), who found that in Norway an oversupply of members of either sex is associated with a decrease in divorce risks. As an explanation, Lyngstad suggested that married people are aware of the risk of losing their spouse when he or she faces more marital alternatives. To counterbalance this risk, they increase their commitment and become “willing to make concessions to keep the marriage in good condition” (Lyngstad 2011, p. 60). The data that Lyngstad employed do not allow inspecting this commitment-based mechanism and the opportunity-based mechanisms separately, but it is possible that both are simultaneously at work. So far, most of the existing evidence suggests that the opportunity mechanism tends to dominate the commitment mechanism.

Educational attainment and the attractiveness of marital alternatives

Early marriage market studies have focused on age as an important determinant of mate attractiveness (Glick and Landau 1950). More recent research also highlights the importance of the cultural and economic resources that individuals have at their disposal (Kalmijn 1994; Lewis 2016). Cultural resources encompass “values and behaviours, such as child-rearing values, political attitudes, cultural literacy, taste in art and music, and styles of speech” (Kalmijn 1994, p. 426). Within couples, similarity in such values and behaviours can lead to mutual reinforcement of world views, create feelings of social confirmation, and facilitate the organization of joint activities. People therefore tend to prefer spouses with similar cultural traits (DiMaggio and Mohr 1985). Economic resources, such as income and property, produce economic well-being and status. Within couples, such resources are typically shared and people therefore tend to prefer partners with high economic resources as this can improve their own economic well-being and status (Kalmijn 1994).

Education has both economic and cultural aspects to it. It is commonly assumed to be "the most important determinant of occupational success in industrialized societies [and] it reflects cultural resources influencing individuals' preference for specific partners" (Blossfeld 2009, p. 514). This is one reason why education is an important factor in mate selection and can explain why men and women tend to prefer similar and more educated spouses over less educated spouses. A similar educated spouse is attractive because of the similarity in cultural resources that comes with similarity in education, but a more educated spouse might also be attractive because of the higher economic resources that often come with higher educational attainment. A less educated spouse, by contrast, is less attractive given the lack of similarity in cultural resources and the lack of economic resources. Our model of mate selection disentangles the economic and the cultural dimension and assumes that agents have a desire for high economic resources but also desire similarity in the cultural dimension of education.

Modelling the link between the gender-gap reversal in education and divorce

The model is a two-sided matching model that simulates mate search over the life courses of several agent cohorts. Agents are born, grow older, enter school, enter the marriage market, leave school, reproduce, and die at some point. The model makes three assumptions that are central for our purposes: (1) individuals have preferences for mates with certain characteristics and potentially leave their partner when they encounter a more attractive alternative; (2) the likelihood that people encounter marital alternatives is largely determined by the structure of the marriage market; (3) similarity in education, all else equal, increases the attractiveness of the available alternatives.

The model takes into account that education usually is associated with cultural and economic resources. In line with earlier research, it approximates people's cultural resources by their educational level and it approximates their economic resources by their life-time earnings prospects (Kalmijn 1994). Thus, the model assumes that agents feel attracted to opposite-sex members who are similar to them in educational attainment, but they feel also attracted to those who have high earnings prospects. Education and earnings prospects, in turn, are positively correlated, but this correlation differs between men and women. Furthermore, the model also considers age as a fundamental determinant of mate attractiveness, next to cultural and economic resources. It assumes that men feel most attracted to women who are in their mid-twenties (everything else being the same), whereas women feel most attracted to men who are slightly older than themselves (Eagly et al. 2009; England and McClintock 2009; Skopek, Schmitz, and Blossfeld 2011).

Agents enter the marriage market and start looking for a spouse when they have reached a marriageable age. The search takes place in the form of meetings with opposite-sex members who are randomly drawn from the marriage market. The model considers that educational tracking tends to increase the likelihood that people with similar educational backgrounds will encounter each other as long as they are in the educational system (Mare 1991; Kalmijn and Flap 2001; Blossfeld 2009). That is, agents progress through the educational system and as long they are in school/at university, they are more likely to meet somebody who is currently attending the same educational level than to meet somebody who is attending a different level or has left school already.

Whenever two agents meet, both need to decide whether they want to start dating; agents who are dating need to decide whether they want to marry. These decisions are modelled probabilistically, based on the assumption of maximizing and risk-aversive behaviour. That is, agents become more likely to accept each other for dating and marriage the more attractive they perceive each other. Yet, agents' aspirations for the attractiveness of their partner decrease as they grow older, given that for both men and women the pool of alternatives usually shrinks with age. This means that in the model, younger agents are more selective in choosing a mate than older agents. This decrease in selectiveness with age is even stronger among women, given that also their attractiveness for men tends to decrease with age.

The model accounts for divorce as the result of repartnering. It does not consider divorce induced by other factors, such as relationship problems or physical abuse (Amato and Previti 2003). Thus, agents tentatively remain on the marriage market even after marriage and continue to meet opposite-sex members. If they encounter an alternative that is more attractive than their current partner, there is a chance that they divorce and repartner. Both the likelihood that agents meet somebody new and leave their current partner decrease with the length of their current relationship, representing the effect of partnership-specific investments that increase over time.

Agent characteristics

The model proceeds in discrete time steps and all time related elements are expressed in these steps. Ten time steps represent one simulation year.[2] Each agent i can be described by its gender g_i (1 = male or 2 = female), age a_i (measured in time steps), the highest educational level that it will ever attain s_i (1 = no education, 2 = primary education, 3 = secondary education, or 4 = tertiary education), earnings prospects y_i, (expressed in five ordered categories), school enrolment status r_i (1 = not in the educational system yet, 2 = in primary education, 3 = in secondary education, 4 = in tertiary education, or 5 = finished education), relationship status l_i (1 = single, 2 = dating, 3 = married, or 4 = divorced), the time it is already in a relationship with its current partner c_i (measured in time steps), and the ideal age it prefers in a partner u_i (expressed in time steps). Table 1 provides an overview of all agent characteristics and Table 2 provides an overview of all other model parameters. The parameter values shown in Table 2 are based on the calibration experiments reported in Grow and Van Bavel (2015), that aimed at generating realistic patterns of educational assortative mating.[3]

–Tables 1 and 2 about here–

Agents' states on the characteristics g_i, s_i, y_i, and u_i are assigned when they enter the simulation and remain stable over their life course. Their states on s_i and y_i are assigned probabilistically, contingent on their gender and birth year, based on empirical data to generate plausible agent cohorts (see details below).

Agents' initial states on a_i, r_i, l_i, and c_i are also assigned when they enter the simulation, but these states can change over their life course. Agents' age (a_i) is set to 0 when they enter the simulation and it increases by 1 at the end of each time step. Given that 10 time steps represent one simulation year, this implies that agents age by 1 year every ten time steps. Agents' relationship status (l_i) is initialized as single and is updated every time they start a new relationship, get married, break up with their current date, or get divorced. Correspondingly, the length of their current relationship (c_i) remains 0 as long as they are single or divorced. From the moment they start dating, the value of c_i increases by 1 at the end of each time step and this increase continues when a dating relationship turns into a marriage. Every time agents experience a break-up (after dating) or divorce (after marriage), the value of c_i is set to 0. Agents' school enrolment status (r_i) is updated as they progress through the educational system, based on the age thresholds shown in Table 3. Every time agents reach the age at which they exit one stage ($A_{ex,r}$) and/or enter the next ($A_{en,r}$), the value of r_i is updated accordingly. Agents leave school once they have finished the level that corresponds with their state on s_i.[4]

–Table 3 about here–

Partner preferences

The overall attractiveness that a given agent i perceives in another agent j is expressed in a single number, the mate value v_{ij}. This value combines information about the attractiveness of j in terms of educational attainment (representing cultural resources), earnings prospects (representing economic resources), and age. Earlier research suggests that low attractiveness in important partner characteristics can usually not be substituted with high attractiveness in other characteristics (Li et al. 2002; Li and Kenrick 2006). In the literature on multi-criteria decision making, such interdependence between different evaluation criteria is often expressed by multiplicative exponential weighting functions (Zanakis et al. 1998). Our model assumes that education, earnings prospects, and age are central partner characteristics that cannot be substituted. It therefore employs a multiplicative exponential weighting function to determine v_{ij}. The function has the form of

$$v_{ij} = \left(\frac{S_{max} - |s_i - s_j|}{S_{max}}\right)^{w_s} \left(\frac{y_j}{Y_{max}}\right)^{w_y} \left(\frac{A_{max} - |u_i - a_j|}{A_{max}}\right)^{w_a}, \quad (1)$$

where S_{max}, Y_{max}, and A_{max} define the maximal education, earnings prospects, and age that agents can reach and the parameters w_s, w_y, and w_a govern how much agents 'penalize' deviations from their ideals in each dimension. The value of v_{ij} can vary continuously between 0–1. The more similar i and j are in their educational attainment, the higher the earnings prospects of j, and the closer j is to the age that i desires in a partner (u_i), the closer v_{ij} comes to 1. Deviations from these ideals decrease the value of v_{ij}, and this decrease is stronger at higher values of w_s, w_y, and w_a. Note that each of the three factors in Eq. (1) is bound to the range 0–1. In combination with the multiplicative structure of Eq. (1), this implies that low attractiveness in one characteristic cannot be substituted by high attractiveness in other characteristics.

Table 2 shows that some of the parameter values that we use in Eq. (1) differ between male (m) and female (f) agents. First, male and female agents differ in the ideal age they desire in partners (u_i). In line with empirical evidence, the preferred age of partners among male agents is 24 years, whereas female agents find partners who are about 2.5 years older than themselves most attractive. Second, male and female agents differ in the weight they attach to each of the three mate characteristics (w_s, w_y, and w_a). The parameterization implies that female agents penalize deviations from the ideal age more than male agents. This in line with the observation men tend to marry women who are increasingly younger than themselves, but also increasingly further away from the ideal age of 24 years, as they grow older (implying a higher tolerance), whereas women tend to marry men who are 2–3 years older, regardless of their own age (implying a lower tolerance) (cf. England and McClintock, 2009). The parameterisation also implies that female agents attach relatively more importance to economic resources than to similarity in cultural resources (represented by earnings prospects and educational attainment respectively). This is in line with the notion that women often have less access to economic resources than men and therefore attach more importance to economic resources (cf. Becker 1991; Kalmijn 1994; Li et al. 2002). Male agents, by contrast, attach similar importance to both dimensions.

Partner search

Agents enter the marriage market at the age of 16 years (A_{marr}= 160). From this age, agents who have no partner invest full effort into finding a spouse, whereas agents who have a partner reduce this effort contingent on the length of the relationship. This is based on the notion that over time, couples generate partnership-specific investments that are lost when the relationship is terminated, thereby reducing the attractiveness of outside alternatives. It is also consistent with the observation that the number of contacts that men and women have with opposite-sex members tends to decrease with relationship length (Rapp et al. 2015). The search effort is represented by the probability that agents will actively seek out an opposite-sex member in a given time step. It is determined as

$$Pr(i\ seek) = e^{-(c_i \beta)}. \tag{2}$$

In Eq. (2), β governs the effect that the length of i's current relationship has on the probability that it will try to meet somebody. We therefore refer to β also as the 'commitment parameter'.

For single and divorced agents, c_i is always 0 and the probability that they will seek out somebody is thus always 1. As Table 2 shows, the value of β is positive and the same for male and female agents. The value implies that agents' inclination to actively seek out alternatives to their current partner decreases concavely with the length of their current relationship and approaches 0 after about 25–30 years (i.e. after 250–300 time steps). This is inspired by the observation that divorces hardly occur after 25–30 years of marriage (cf. Kulu 2014).

If agent i seeks out somebody in the current time step, an opposite-sex member j is selected randomly from one of two sets of agents on the marriage market: agents who have the same school enrolment status as i (i.e.$r_i = r_j$), or agents who have a different school enrolment status than i (i.e.$r_i \neq r_j$). The probability with which each set is chosen is determined by the 'structuring parameter' δ ($0 \leq \delta \leq 1$), so that

$$Pr\left(r_i = r_j\right) = \delta \tag{3a}$$

and

$$Pr\left(r_i \neq r_j\right) = 1 - \delta. \tag{3b}$$

The closer the value of δ is to 1 (0), the more likely agents are to meet somebody with the same (different) school enrolment status. In both cases, j is randomly selected from all agents in the respective set. As Table 2 shows, the chosen value for δ implies that while in school, agents mostly encounter people who are currently attending the same educational level. Conversely, agents who have left school already are most likely to meet agents who also have left school.

Dating, marriage, and divorce decisions

Whenever two agents meet, they need to decide whether they want to start dating, and dating can, over time, lead to marriage. Marriages, in turn, can end in divorce if agents meet an alternative that is more attractive than their current partner and that also wants to start dating them. Thus, divorce is always the result of repartnering.

More specifically, whenever two agents meet, they assess each other's mate value (v_{ij}) and use this value to decide whether they want to start dating. Agents who have no partner perceive any opposite-sex member j as a potential spouse and therefore always consider dating j. By contrast, agents who are currently dating or married only consider those as a potential spouse whose mate value is higher than that of their current partner (i.e. when $v_{ij}^{alternative} > v_{ij}^{partner}$). If they encounter such an alternative, there is a chance that they leave (if they are dating) or divorce (if they are married) their current partner.

The probability that i is willing to date alternative j and to leave/divorce its current partner for this, if there is one, is determined by

$$Pr(i\ date\ j) = \left(1 - e^{-(a_i v_{ij} \sigma)}\right) e^{-(c_i \beta)}, \quad (4)$$

where σ governs the pressure to find a partner that agents experience as they become older; we therefore refer to σ also as the 'age pressure parameter'. The first factor of Eq. (4) implies that i's willingness to start dating j increases with j's mate value and with i's age (assuming that $\sigma > 0$). The second factor of Eq. (4) implies that this willingness is attenuated when agents are currently in a relationship (assuming that $\beta > 0$). Note again that c_i is always 0 for agents without a partner. For them, the second factor of Eq. (4) is therefore always equal to 1. Thus, all that matters for their willingness to start dating is the mate value of the potential partner and their own age in combination with σ. By contrast, for agents who are currently dating or married, the value of $Pr(i\ date\ j)$ is attenuated by the time they are already in the relationship (c_i), in combination with the commitment parameter (β). Two agents only start dating, and leave/divorce possible current partners for this, when both are willing to date. This implies two independent decision processes, in which Eq. (4) is applied separately to i and j.

The longer agents are already dating their current partner, the more willing they become to marry and therefore to propose marriage to/accept a marriage proposal from their partner.

From the moment agent i (or j) proposes marriage to its partner j (i), the proposal remains intact until j (i) agrees to marry, or until one of them terminates the relationship or dies. They get married at the moment both agree to marry. The probability that agent i proposes to j, or is willing to accept a proposal from j, is calculated as

$$Pr(i\ marry\ j) = \left(1 - e^{-(a_i v_{ij} \sigma)}\right)\left(1 - e^{-(c_i \beta)}\right). \quad (5)$$

Eq. (5) holds that agents are the more likely to propose marriage to/accept a marriage proposal from their partner, the higher the mate value of their partner (v_{ij}), the longer the relationship (c_i), the higher the commitment parameter (β), the older they are (a_i), and the higher the age pressure parameter (σ).

As Table 2 shows, in the above decision processes females experience a stronger age pressure (σ) than males. This builds on the notion that both men and women suffer from a smaller pool of alternatives as they grow older, but women suffer additionally from the fact that men prefer women who are in their mid-twenties.

Fertility and mortality

The model in Grow and Van Bavel (2015) assumes that population size remains constant over time and that agents' risk of death increases with age at the same rate for men and women. Here, we rely on more realistic assumptions about fertility and mortality. The reason is that the average life expectancy of men is lower than that of women and this can lead to a skewed sex ratio, in particular among older individuals. This, in turn, might affect their repartnering opportunities (Dyson 2012). To account for this, we rely on annual country-, age-, and gender-specific fertility and mortality rates obtained from empirical data (see details below). This enables us to realistically model fertility among female agents between 12–55 years of age ($a_i \geq 120$ and $a_i \leq 550$) and mortality among all agents between 0–110 years of age ($a_i \geq 0$ and $a_i \leq 1{,}000$). We assume that 105 males are born for every 100 females (Guilmoto 2012), so that there is a .512 chance that a new born agent is male.[5]

Experimental setup and measures

The model in Grow and Van Bavel (2015) used empirical data provided by the International Institute for Applied Systems Analysis/Vienna Institute of Demography (IIASA/VID) (Lutz et al. 2007; KC et al. 2010) and the European Community Household Panel for initializing agents in terms of educational attainment and earnings prospects. This makes it possible to study mate search under plausible marriage market conditions in 12 European countries. Figure 1 shows how the sex ratio among the highly educated has changed between 1970 and 2015 in these countries according to the IIASA/VID data.

–Figure 1 about here–

Here, we additionally relied on country-level data from the Human Fertility Database/Human Fertility Collection[6,7] and the Human Mortality Database[8] to implement realistic fertility and mortality rates (see further details in the online supplementary material). Note that the input data for the model in Grow and Van Bavel (2015) was provided in five-year intervals. To align this data with the annual fertility and mortality rates that we used here, we assigned the original education/earnings prospects data of each five-year interval to the year in the centre of the respective interval and linearly interpolated the data between these years. The combined data enabled us to study mate search under plausible marriage market conditions over the period 1921–2012. We focused on the dissolution risks of marriages formed between 1950–2004 and the simulation period covers the years 1921–2064. We chose 2064 as the stopping year to avoid that censoring might pose a problem among later marriage cohorts. We used the data from the year 2012 for initializing newly born agents in all subsequent simulation years.

We focused on the shares of marriages in a given marriage cohort that had dissolved by the end of the simulation runs. We were particularly interested in the relative divorce risks of hypogamous and hypergamous marriages and assessed this by

$$R = log\left(\frac{A}{B}\right), \tag{6}$$

where A and B refer to the average shares of hypogamous and hypergamous marriages that had dissolved across runs. On this measure, a value larger (smaller) than 0 indicates that hypogamous marriages were more (less) likely to dissolve than hypergamous marriages; a value of 0 means that there is no difference in the likelihood of divorce. We refer to R also as the 'relative divorce risk'.

We measured the structure of the marriage market in which divorces occurred with the F-index proposed by Esteve et al. (2012). This index expresses the educational advantage that women have in the population as the probability that any randomly selected woman will be more educated than any randomly selected man. Accordingly, a higher F-value indicates a higher female educational advantage. The measure is calculated as

$$F = \frac{p_4^f(p_3^m+p_{1+2}^m)+p_3^f p_{1+2}^m}{1-\left(p_{1+2}^f p_{1+2}^m+p_3^f p_3^m+p_4^f p_4^m\right)}, \tag{7}$$

where $p_{s_i}^m$ and $p_{s_i}^f$ refer to the proportions of men and women who belong to each category of s_i. The measure ranges from 0 to 1. Values closer to 0 (1) indicate that no woman (man) is more educated than any man (woman); a value of .5 indicates that men and women are on average similarly educated. We calculated F for a given year based on the IIASA/VID data. We focused on men and women in the age range 20–49 years, given that this is typically the prime age for (re)marriage. Note that in Eq. (7) (and all other calculations reported below), we combined the educational categories 1 and 2, given that the category 1 was virtually empty in most countries and years.

All results are based on averages obtained from 1,000 independent simulation runs per country. Each run was preceded by a burn-in phase of 600 simulation steps to ensure that agents who started looking for a partner at the beginning of the simulation did so on a realistic marriage market (see details in the online supplementary material).

Results

Figure 2 plots the average of the shares of marriages that had dissolved by the end of the simulation runs across countries by marriage type. In total, about 13% of all marriages ended in divorce. This value tended to increase from about 11% among marriages formed in the years 1950–54, to about 14% among marriages formed in the years 1985–89. Comparing these values with empirical data is difficult, because information about divorce reasons is hard to come by. There are often multiple reasons and concerns for social desirability might lead to underreporting of new relationships. However, the existing empirical evidence suggests that our model outcomes are realistic. For example, Amato and Previti (2003) found in a longitudinal survey of couples in the US that marital infidelity was reported as one reason for divorce among about 21% of all couples that had divorced. Considering that in the US about 50% of all first marriages end with divorce within 20 years (Copen et al. 2012), this implies that about 10% of all first marriages might end in divorce because of a third person.

–Figure 2 about here–

Figure 2 shows that homogamous marriages were least likely to experience divorce, although the divorce rate among these marriages slightly increased until the marriage cohort 1985–89. Similar to the empirical trends reported by Schwartz and Han (2014) for the US, in our simulations hypergamous marriages were less likely to dissolve than hypogamous marriages in early marriage cohorts, but this difference decreased in more recent cohorts. The difference disappeared in marriage cohort 2000–04.

Figure 2 shows cross-country averages and masks between-country variation. Figure 3 thus shows the results separately for each country and focuses on the relative divorce risk (R).

In many countries, the value of R started above 0 in early marriage cohorts and approached 0 in later cohorts. In Denmark, Finland, and Portugal, R even became lower than 0. This means that over successive cohorts, the divorce risk of hypogamous marriages tended to decrease, compared to the risk of hypergamous marriages. In some countries, hypogamous marriages even became *less* likely to divorce than hypergamous marriages. Sweden is the only country in which the divorce risk of hypogamous marriages was lower than that of hypergamous marriages in all cohorts. But even this already low relative risk decreased over successive cohorts. The only countries that did not show a clear decrease in R were Ireland and the United Kingdom.

–Figure 3 about here–

The results suggest that we might expect cohort trends in divorce risks across Europe similar to those reported by Schwartz and Han (2014) for the US. We argue that this pattern might result from increases in the educational attainment of women relatively to that of men. To assess this more directly, we needed to measure the structure of the marriage market in which divorces had occurred. This is complicated by the fact that even if two marriages have formed at the same point in time, they might have dissolved at different points in time, and therefore under different conditions. This makes it difficult to determine precisely *when* to measure the structure of the marriage market. To deal with this issue, we used the average time from marriage to divorce as a reference for approximating the structure of the marriage market in which divorces had occurred. Figure 4 shows a histogram of the durations of the marriages that had dissolved in all 12,000 simulation runs. The distribution resembles the distribution reported in empirical research (Kulu 2014) and peaks after about 5 years (i.e. 500 time steps) of marriage, with an average of about 6.7 years (i.e. 670 time steps). Based on this, we calculated for each marriage cohort the F-index six to ten years later for assessing the relevant marriage market structure. For example, for marriages formed in 1950–54, we calculated F for the year 1960.[9] Figure 5 plots the association between F and R for all marriage cohorts in each of the 12 countries. As female agents became increasingly more educated than male agents (i.e. as F increased), the risk that hypogamous marriages dissolved, compared to hypergamous marriages, decreased (i.e. R decreased). This supports our argument.

–Figures 4 and 5 about here–

The association shown in Figure 5 might result from a decrease in the absolute divorce risk among hypogamous marriages, an increase in the absolute divorce risk among hypergamous marriages, or a combination thereof. Figure 6 assesses these alternative processes by plotting the shares of hypogamous and hypergamous marriages that had dissolved against the F-index, separately per country. The figure suggests that the driver of the convergence in divorce risks varied across countries. In some countries (Germany, Denmark, Finland, and Sweden), increases in the female educational advantage reduced the divorce risk among hypogamous marriages and increased it among hypergamous marriages. In a second group of countries (Belgium, Spain, France, and Greece), the divorce risk increased among both marriage types, but this increase was stronger among hypergamous marriages than among hypogamous marriages. In a third group of countries (Netherlands and Portugal), the divorce risk among hypogamous marriages remained comparatively stable, whereas the risk among hypergamous marriages increased. Only in Ireland, divorce risks decreased among both marriage types, but this decrease was stronger among hypergamous marriage than among hypogamous marriages. In the United Kingdom, there was no clear difference in the association between F and the divorce risks of the different marriage types.

–Figure 6 about here–

Finally, the model distinguishes between individuals' cultural and socioeconomic resources, represented by agents' educational attainment (s_i) and earnings prospects (y_i). This makes it possible to assess the effect that preferences for each resource have on divorce risks.

To this end, Figure 7 compares the outcomes of the full model with the outcomes of a model in which similarity in education does not affect mate attractiveness (i.e. $w_s^m = w_s^f = 0$) and a model in which earnings prospects do not affect mate attractiveness (i.e. $w_y^m = w_y^f = 0$). In the model without educational preferences, the relative divorce risk (R) decreased over successive cohorts, but the intercept was lower and the slope was flatter than in the full model. One explanation for this is that without preferences for educational attainment, the effect that the gender-gap reversal in education has on divorce risks occurs indirectly (and therefore is weaker), via agents' preferences for earnings prospects, which are correlated with educational attainment. In the model without preferences for earnings prospects, the slope was similar to that of the full model, but the intercept was much lower and R became negative in the cohort 1970–74. One explanation for this is that earnings prospects and education are imperfectly correlated and that the earnings distribution is usually more compressed among women than among men (cf. England 2004). Some highly educated female agents might thus have an 'incentive' to leave a lower educated spouse for another lower educated spouse, as long as the new spouse has higher earnings prospects. For highly educated male agents who have a lower educated spouse, this is less likely to happen, given that there is less variation in the incomes of lower educated women. These differences, in turn, are likely to hamper the decrease in the divorce risk of hypogamous marriages compared to hypergamous marriages.

–Figure 7 about here–

Discussion and conclusion

The reversal of the gender gap in education has had important consequences for patterns of educational assortative mating. In this paper, we explored some of the consequences that it might have had for patterns of divorce. The results of our simulation experiments suggest that an increase in the educational attainment of women relatively to that of men might lead to a convergence in the divorce risks of hypogamous and hypergamous marriages. The results also suggest that this convergence might occur even if men and women did not have a preference for similarity in cultural resources with their partners and might occur earlier if they did not care about the economic resources of their spouses.

The mechanism that we have described focuses on the interplay between people's partner preferences and changes in the structure of the marriage market. It does not consider that the norms that surround family formation might have changed over time, as suggested by Schwartz and Han (2014). Yet, it seems possible that our opportunity-based mechanism could reinforce the norms-based mechanism described by Schwartz and Han. Schwartz and Han suggested that the number of hypogamous marriages has increased over the years, partly because the number of highly educated women has increased relatively to that of men. The increasing prevalence of hypogamy, in turn, has rendered this type of marriage less deviant and thereby has decreased normative pressures that might affect the divorce risk among hypogamous couples. The mechanism that we describe might strengthen this process, by reducing the likelihood that hypogamous couples divorce, compared to the likelihood that hypergamous couples divorce. This might further reduce the non-normative character of hypogamous marriages and thereby further reduce their divorce risk. Future simulation research could assess this possibility by introducing marital satisfaction as an additional cause of divorce into the model, that might lead to marital dissolution even when agents have not encountered a more attractive marital alternative yet. The marital satisfaction of couples, in turn, could be modelled endogenously with respect to the share of marriages that have similar/different educational characteristics as the couple itself.

Next to norms, the model also neglects a number of other factors that might impinge on divorce decisions. One of the most important factors is the presence of young children, which has been shown to considerably reduce the divorce risk of couples (Lyngstad and Jalovaara

2010) and reduces the likelihood of remarriage among divorced individuals (Ivanova et al. 2013; Theunis et al. 2015). If hypogamous and hypergamous marriages differ in their fertility behaviour, this might affect differences in the relative divorce risk between these marriage types and this might affect the mechanism that we have explored. Future research should therefore extend our model to include such individual- and couple-level factors that might lead to systematic differences in divorce risks between hypogamous and hypergamous marriages, to assess the robustness of the dynamics that we have described.

The mechanism that we have described potentially applies to all unions, also to non-marital cohabitation, which has become more prevalent in recent decades. Yet, one issue that might arise in this respect is that cohabiters are often less committed than married people, which leads to a higher dissolution risk among cohabitations (Forste and Tanfer 1996). This might affect the proposed mechanism, if couples with certain educational combinations are more likely than others to opt for cohabitation. Future empirical research should therefore disentangle marriages and cohabitations when exploring the relation between the gender-gap reversal and dissolution risks, to take possible variation in commitment by union type into account.

Finally, our results also offer a new explanation for the increasingly negative educational gradient in divorce risks among women, that has been observed in Western countries over the last decades (Härkönen and Dronkers 2006). According to our model, the reversal of the gender gap in education might have reduced the divorce risk among highly educated women in hypogamous marriages, while it increased the divorce risk among lower educated women in hypergamous marriages. This may explain at least part of the fact that the average divorce risk among highly educated women has decreased relative to the divorce risk among lower educated women.

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Tables and figures

Table 1 Overview of agent-variables

Variable	Description	States
g_i	Gender	1 = male 2 = female
a_i	Age	Time steps: $\in \{0, 1, \cdots, \infty\}$
s_i	Educational attainment	1 = no education 2 = primary education 3 = secondary education 4 = tertiary education
r_i	School enrolment status	1 = not in the educational system yet 2 = in primary education 3 = in secondary education 4 = in tertiary education 5 = finished education
l_i[1]	Relationship status	1 = single 2 = dating 3 = married 4 = divorced
c_i	Duration of current relationship	Time steps: $\in \{0, 1, \cdots, \infty\}$
u_i[2]	Ideal age that agent i prefers in a partner	Time steps: $\in \{0, 1, \cdots, \infty\}$ (for male agents fixed at 240, for female agents equal to $a_i + 25$)
y_i	Earnings prospects	$\in \{1,2,3,4,5\}$
v_{ij}	Mate value that agent i perceives in agent j	$0 \leq v_{ij} \leq 1$

[1] Compared to Grow and Van Bavel (2015), we added the category 'divorced' to identify agents who have experienced divorce and who have not repartnered yet.

[2] u_i is denoted α_i in Grow and Van Bavel (2015).

Table 2 Overview of model parameters

Parameter	Description	Values in experiments
I	Total number of agents in the initial population	1,000
$A_{en,r}$, $A_{ex,r}$	Age at which agents enter and exit a given educational level r	See Table 3
A_{marr}	Age at which agents enter the marriage market	160
S_{max}	Maximal educational attainment of agents	4
Y_{max}	Maximal earnings prospects of agents	5
A_{max}	Maximal age of agents	1,100
w_s^m, w_s^f	Importance that male and female agents attach to similar education of partners	0.934, 0.385
w_y^m, w_y^f	Importance that male and female agents attach to high earnings prospects of partners	1.025, 1.201
w_a^m, w_a^f	Importance that male and female agents attach to the age of partners	6.887, 14.895
β^m, β^f	Commitment parameter for male and female agents	0.015, 0.015
σ^m, σ^f	Age pressure parameter for male and female agents	0.0015, 0.0030
δ	Structuring effects of the educational system	0.9

Table 3 Overview of ages at which agents transit between educational levels

Educational level	$\boldsymbol{r}$	$A_{en,r}$	$A_{ex,r}$
Not in the educational system yet	1	0	60
In primary education	2	60	100
In secondary education	3	100	190
In tertiary education	4	190	240

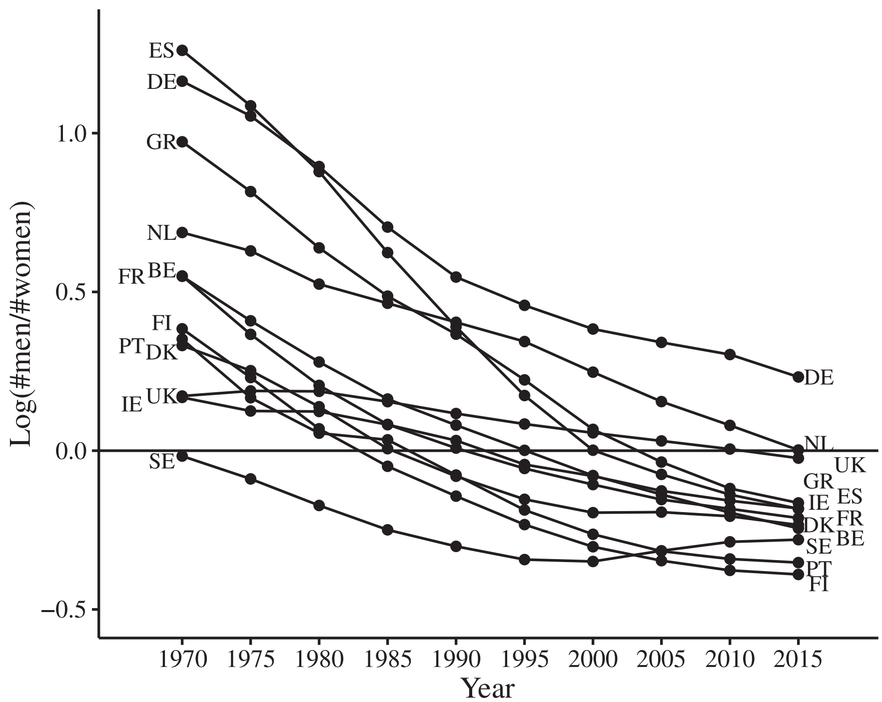

Figure 1 Log of the sex ratios among highly educated individuals aged 30–49 years in 12 European countries between 1970 and 2015

Note: Selected countries are Belgium (BE), Germany (DE), Denmark (DK), Spain (ES), Finland (FI), France (FR), Greece (GR), Ireland (IE), the Netherlands (NL), Portugal (PT), Sweden (SE), and the United Kingdom (UK); the selection is based on Grow and Van Bavel (2015). Calculations are based on the global educational trend scenario in the reconstructions and projections of educational attainment by country, year, gender, and five-year birth cohort provided by the International Institute for Applied Systems Analysis/Vienna Institute of Demography (IIASA/VID) (Lutz et al. 2007; KC et al. 2010). High education is operationalized as ISCED 5–6.

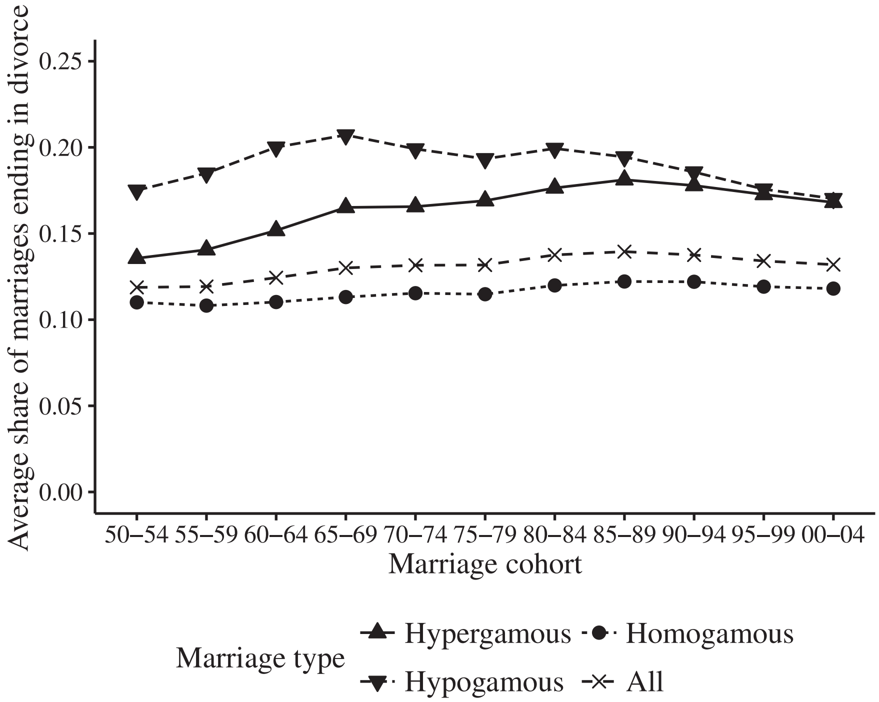

Figure 2 Average shares of different marriage types that had ended with divorce by marriage cohort

Note: We first calculated the mean shares for the different marriage types that had dissolved across runs within countries and then calculated the averages of these means across countries.

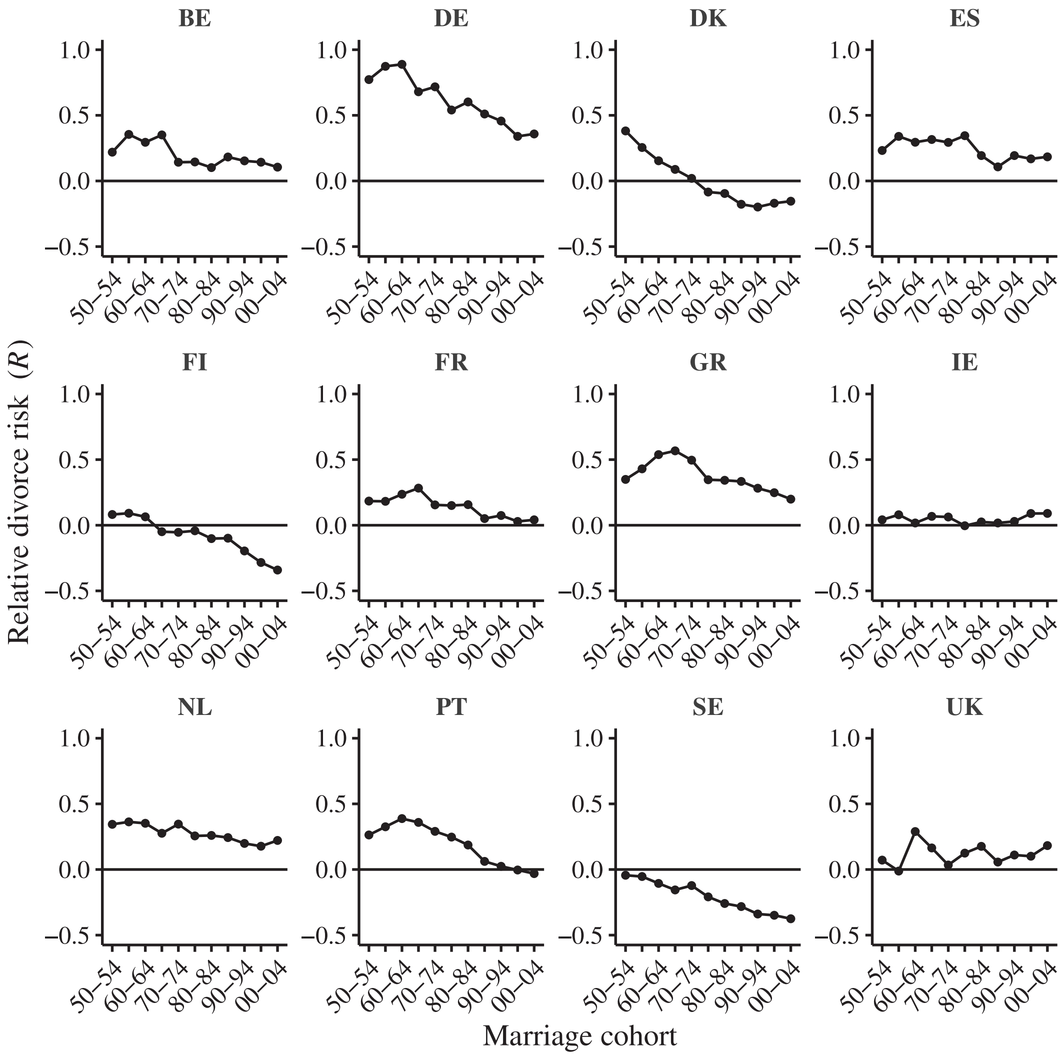

Figure 3 Relative divorce risk of hypogamous and hypergamous marriages (R) by marriage cohort

Note: We first calculated the average shares of different marriage types across runs within countries and then used these averages to calculate R.

Figure 4 Distribution of marriage durations among marriages that had ended with divorce

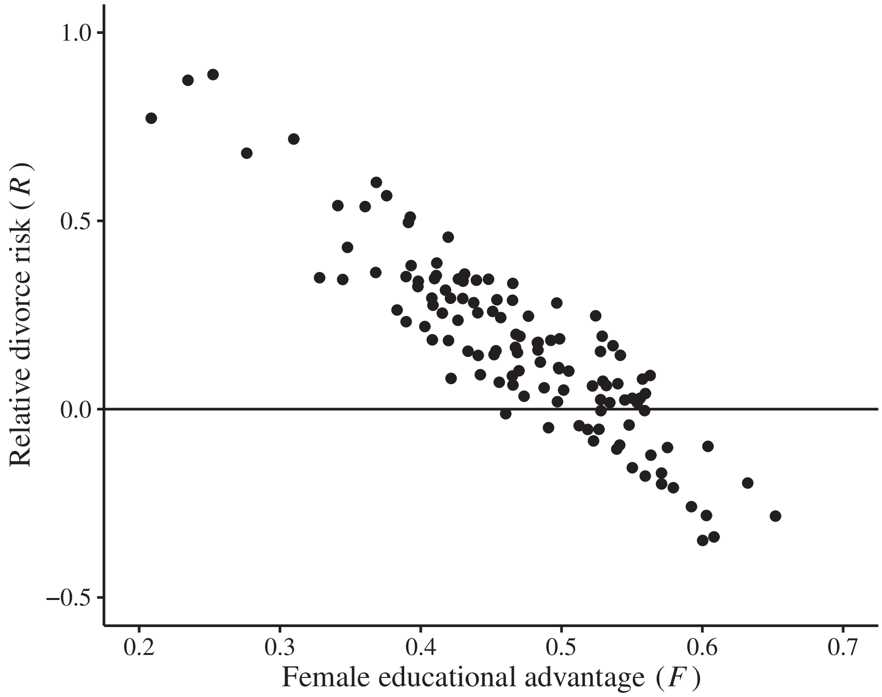

Figure 5 Relative divorce risk of hypogamous and hypergamous marriages (R) contingent on the female educational advantage (F)

Note: We first calculated the average shares of different marriage types across runs within countries and then used these averages to calculate R for each marriage cohort.

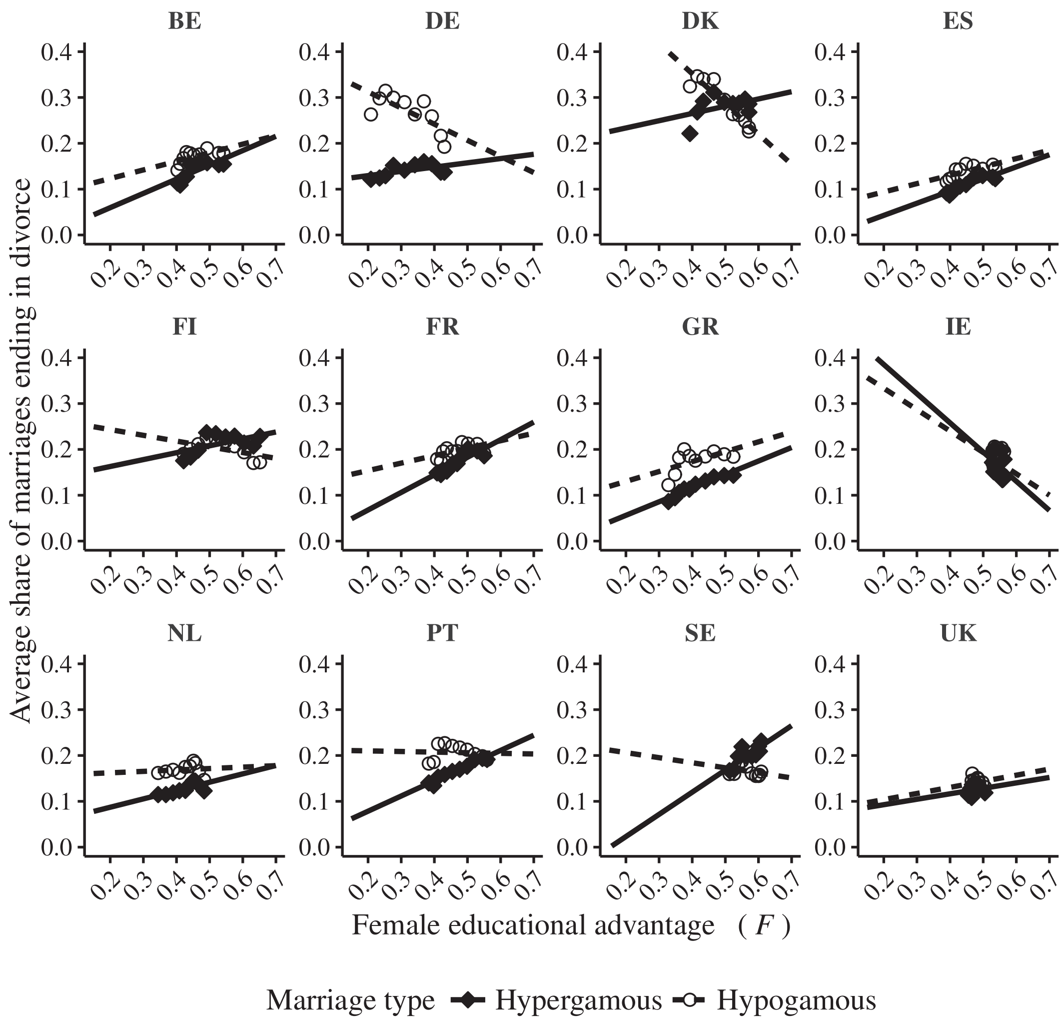

Figure 6 Average shares of hypergamous and hypogamous marriages that had ended with divorce contingent on the female educational advantage (F)

Notes: Trend lines are based on ordinary least square regression models. We first calculated the mean shares for the different marriage types across runs within countries and then calculated the averages of these means across countries.

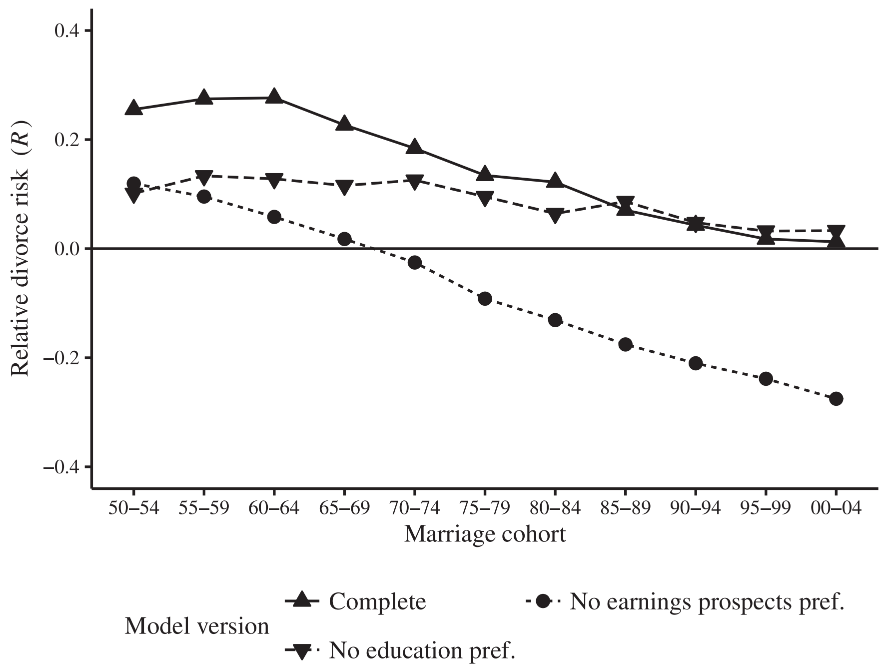

Figure 7 Relative divorce risks of hypogamous and hypergamous marriages (R) by marriage cohort

Note: We first calculated the average shares of different marriage types across runs within countries, then calculated the averages across countries, and finally used these averages to calculate R.

Endnotes

1 We have implemented the model in NetLogo (version 5.2.0, Wilensky 1999) and the code can be obtained from [*link to be established*], together with a standardized model description in the ODD+D format (Müller et al. 2013), all input data, scripts to reproduce our analysis in the statistical programming environment R (R Core Team 2014), and an additional analysis to determine varaibility in model outcomes and the necessary number of simualtion runs. The ODD+D description also contains an overview of the models' process scheduling and a detailed description of the input data.

2 The choice of 10 time steps to represent one simulation year—in contrast to choosing, for example, 12 steps to represent the twelve months of the year—makes it easier to implement the model in computer code, given that personal computers usually use the decimal system for counting.

3 We have adjusted the parameterization that Grow and Van Bavel (2015) used in three aspects. First, we have increased the size of the initial agent population from 500 to 1,000, to increase the reliability of our results, given that divorce happens less often than marriage. Second, we have increased the value of A_{max} = 800 to A_{max} = 1,100, to make full use of the age range covered by the empirical mortality rates that we use in this paper (see details in the model description). Third, because of this change in A_{max}, we have also adjusted the values of w_a^m and w_a^f. These parameters govern in Eq. (1) the effect that deviations from the ideal age that agents prefer in partners (u_i) have on v_{ij}, contingent on the value of A_{max}. To account for the larger value of A_{max}, we have multiplied w_a^m and w_a^f by 1,110/800 = 1.375. In this way, we can consider values of a_i > 800, without altering the functional relation between $u_i - a_j$ and v_{ij} for values of $a_i \leq 800$, as defined by Grow and Van Bavel.

4 The only exception from this are agents with s_i = 2 (primary education), who transition from primary to secondary education and leave school at a_i =160. This implements the fact that for

those who participate in education, a minimal number of years in the educational system is usually mandatory.

5 To assess the sensitivity of the model to these changes, we have inspected the patterns of educational assortative mating that the adjusted model generates and compared the results with the outcomes of the validation experiments reported in Grow and Van Bavel (2015). The model that we employ here generates outcomes that are very similar to the outcomes of the model in Grow and Van Bavel.

6 Human Fertility Database. Max Planck Institute for Demographic Research (Germany) and Vienna Institute of Demography (Austria). Available at www.humanfertility.org (data downloaded on 24.04.2016).

7 Human Fertility Collection. Max Planck Institute for Demographic Research (Germany) and Vienna Institute of Demography (Austria). Available at www.fertilitydata.org (data downloaded on 24.04.2016).

8 Human Mortality Database. University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany). Available at www.mortality.org or www.humanmortality.de (data downloaded on 24.04.2016).

9 Given that the IIASA/VID data only provide information from 1970, we approximated the F-index for 1960 and 1965 with the data from 1970, focusing on the age groups that would have been 20–49 years of age in 1960 and 1965.