Childlessness and Inter-Temporal Fertility Choice *

Fabian Siuda

ifo Institute

University of Munich

Latest Version Here

December 14, 2019

This paper develops and estimates a dynamic structural model of fertility with endogenous marriage formation, linking the timing of fertility to its intensive (number of children) and extensive (having children) margin. The model features rational, forward-looking agents who make decisions on marriage and fertility, and are exposed to declining fecundity rates over time. In every period, agents face a trade-off between work and child-rearing, and across time there is a trade-off between having children early or late in life. The model parameters are identified using four distinct facts of the 2008 and 2012 German Microcensus: (i) fertility until age 30 decreases with education for married and single women, (ii) fertility after age 30 increases with education for married and single women, (iii) childlessness increases with women's education, (iv) marriage rates decrease with education for women and increase with education for men. I obtain three main insights. First, postponement of childbirth combined with the natural decline of fecundity over time can explain up to 15% of childlessness, depending on education. Second, by estimating the model separately for East and West Germany, I find that institutions and economic conditions matter: the two major factors for childlessness in West Germany are postponement of childbirth and high opportunity costs of children due to lack of public childcare. By contrast, in East Germany, social sterility plays a larger role. Finally, using the estimated model parameters for counterfactual analysis, I evaluate consequences of reoccurring labor market interruptions and policies aimed at reconciling work and family life.

JEL-classification: J10, J12, J13, J22

Keywords: fertility, childlessness, marriage, labor supply

*I am deeply indebted to Helmut Rainer and Uwe Sunde for their continuous support and patient advice. I thank Vojtěch Bartoš, Davide Cantoni, Natalia Danzer, David De La Croix, Jeremy Greenwood, Eleonora Guarnieri, Timo Hener, Mathias Iwanowsky, Dirk Kruger, Corinne Low, Patrick Reich, Andreas Steinmayr, Michèle Tertilt, Peter Zorn and audiences at the ifo Institute, the 10th Interdisciplinary Ph.D. Workshop Perspectives on (Un-)Employment at the IAB in Nuremberg, ifo Conference Economic Uncertainty and the Family, the 21st IZA Summer School in Labor Economics, the EDGE Jamboree at the University of Cambridge, and the University of Pennsylvania for helpful comments and suggestions. Contact: siuda@ifo.de, Link to Homepage

1 Introduction

From the second half of the 20th century until today, sustained below-replacement fertility has become a common phenomenon in many developed countries. Germany, the world's fifth largest economy, is a particular case in point: Until the late 1960s, Germany's total fertility rate was still well above replacement level, but then declined sharply in the decade that followed. From the early-1980s until the mid-2010s, the fertility rate has been below 1.5, at times as low as 1.3, which is far below the 2.1 children per women necessary to maintain a stable population size.

What is behind this decrease in the total fertility rate is not so much a change along the intensive margin of fertility as it is a change along its extensive margin. For example, among women born between 1945 and 1965, the average number of children per mother decreased moderately from roughly 1.8 to 1.6, whereas the rate of childlessness almost doubled from about 12% to more than 20%. This demographic development, and the rise of childlessness in particular, is highly relevant for economic and social outcomes. At the macro level, rising childlessness is one important factor that increases the ratio of older to working-age adults, implying that the latter need to contribute a larger share of their income to support social security and health care for the elderly. At the micro level, parenthood entails substantial social and psychological benefits, and so childlessness—especially if involuntary—may lower people's well-being. Despite the importance of the issue, there is still a lack of theoretically founded research that looks into the mechanisms and parameters governing childlessness and fertility in the population at large. In particular, the interplay between economic conditions that lead to women postponing children and childlessness that results from naturally declining fecundity by age has not been thoroughly assessed.

In this paper, I develop and estimate a dynamic structural model of childlessness and fertility with endogenous marriage formation. The model's key innovation is that it endogenizes the timing of fertility in the context of childlessness. This allows me to address long-standing questions related to the relationship between fertility postponement and childlessness. In particular, the magnitude of this postponement effect has not yet been assessed. My model fills this gap by linking the timing of fertility to its intensive and extensive margin. Moreover, by implementing the model in the context of Germany, and by focusing on cohorts of East and West German women and men socialized in different political regimes (the FRG versus the GDR), I provide a new perspective on how institutions shape childlessness and fertility.

The economy features men and women who, in the beginning of the first period, are matched with a potential partner of the opposite sex and decide whether to enter marriage or not.[1] In the first two periods of the model, couples and singles[2] make decisions about consumption and fertility. A key feature of the model is that individuals are faced with a natural decline of fecundity over time: in the first period, individuals are "young" and have a relatively high natural fecundity. In the second period, they are "old" and their ability to conceive is lower. In the third and final period of the model, women and men are no longer able to reproduce; Individuals who decide to distribute the birth of their children over both fertile periods will experience lower wages as a result of long lasting absence from the job market due to child-rearing.[3]

In every period, individuals face a trade-off between child-rearing and income-earning. The timing of fertility, however, involves an inter-temporal trade-off: working less to have children early has a negative impact on earnings potential later in life, due to negative experience effects on wages. At the same time, however, the decision against children, to accumulate work experience, carries the risk of not being able to conceive later in life. Marriage alleviates these trade-offs as it allows partners to share the time cost of raising children and other household chores. In addition, it generates economies of scale from sharing household public goods. Finally, marriage is assumed to be the only path to fatherhood for men.

I use the model to characterize various fertility regimes that emerge from optimal behavior. In terms of the intensive margin of fertility, I decompose the fertility of mothers into "early" and "late" fertility. In terms of the extensive margin of fertility, I differentiate between voluntary and involuntary childlessness. Voluntary childlessness can be in form of social sterility[4] or opportunity cost. Involuntary childlessness is driven by biological sterility and postponement of childbirth in combination with decreases in biological fecundity. The distinction of those channels allows for a better understanding of the drivers of childlessness and the economic origins of low fertiltiy rates.

[1] Marriage formation is assumed friction-less.

[2] For a clearer distinction and to avoid confusion I refer to "never married" as "single".

[3] These lower wages can be a result of discrimination or human capital effects beyond the effect of part time work for a short period of time.

[4] Social sterility refers to a too low level of consumption if having children.

I estimate the model using simulated methods of moments, and exploit four distinct demographic facts in Germany—some well-known and others less so—to identify the model parameters: (i) fertility until age 30 is decreasing for married and single women in mother's education, (ii) fertility after age 30 is increasing for married and single women in mother's education, (iii) childlessness is increasing in women's education, (iv) marriage rates are decreasing in education for women and increasing in education for men. Identification is achieved through differences in initial wages, returns to experience by education, and the resulting fertility consumption trade-offs.

The main findings are threefold. First, I estimate that the postponement effect accounts for 7.8% of total childlessness (or 33.3% of involuntary childlessness). Depending on women's education, the share increases from 4.4% (20.7%) for women with low levels of education to 15.6% (68.2%) for women with the highest level of education. For married women, childlessness is mostly a choice driven by high opportunity cost. When it comes to single childless women, the wish to have children is often restrained by economic conditions. For involuntary childlessness, the importance of biological sterility is decreasing in importance with growing levels of education. Postponement effects in combination with decreasing fecundity by age become more important with education. I quantify the individual's loss in utility for realization of involuntary childlessness. Involuntary childlessness has two counteracting effects on lifetime utility: disutility due to the lower number of children and a higher utility due to higher consumption as more labor income is available. I find that being unable to conceive already early in life results in a negative effect on lifetime utility (measured in equivalent net present value consumption) four times the size of the effect when realized only later in life. However, the labor income effect is larger for involuntary childlessness that occurs early in life, thus making involuntary childlessness more costly in relative terms.

Second, I compare former East and West German states. This comparison is interesting for two reasons: (i) Compared to West Germany, public provision of childcare was (and partly still is) fundamentally different (ii) non-employment and taking time off work was less acceptable for women (and even more so for men) in East Germany. I find lower time cost of having children and a larger negative wage effect of spacing children across time in East Germany. Unlike many reduced form empirical studies that look at immediate effects on "at-risk" sub-groups of the population, the results of this study apply to the general population. Furthermore, I find that social sterility and postponement of children explain a larger share of childlessness in West Germany.

Third, I perform counterfactual analyses of fertility and childlessness for increases in public provision of childcare and changes in labor market conditions. In particular, I simulate the effect of the full application of the East German public childcare system to West Germany and the application of the East German wage penalty for long term private child-rearing to West Germany. These counterfactuals indicate that reductions in the costs of children mainly affect the timing of childbirth rather than the final number of children. Childlessness can be reduced significantly by an expansion of available public childcare for both married and unmarried women. Furthermore, I show that an expansion of publicly available childcare that would contribute to the development of children's human capital can function as a counteracting measure to increases in wage penalties of extended child-rearing times.

This paper contributes to two distinct strands of literature: The literature on childlessness and the literature on optimal allocation of children across time. The first paper separating the extensive from the intensive margin of fertility is by Baudin, De La Croix, and Gobbi (2015), who investigate this issue in a static one period model using US data. Myong, Park, and Yi (2018) build on this model to address the impact of social norms, such as Confucianism, on fertility along both dimensions for a large set of East Asian countries. In a follow-up paper, Baudin, De La Croix, and Gobbi (2017) investigate cross-country variation in fertility and childlessness. I build on the model of Baudin, De La Croix, and Gobbi (2015) and expand the model to a three period setting.

Earlier work on labor market participation and skill acquisition includes Rios-Rull (1993) who builds an overlapping generation model in which individuals choose between market and home production. In this way, the model endogenously creates heterogeneous agents through individual choices. Caucutt, Guner, and Knowles (2002) find that when women face a high wage penalty for childbirth, they tend to postpone having children and build up human capital first. Greenwood, Guner, and Knowles (2003) and Regalia, Rios-Rull, and Short (2011) propose household models which include fertility and parental investment in a marriage market equilibrium framework. Adda, Dustmann, and Stevens (2017) estimate the short and long-term career cost of children in a model of labor supply and fertility with occupational choice.

My paper combines the two strands of literature by adding fertility timing and the resulting wage dynamics to the model of Baudin, De La Croix, and Gobbi (2015). Compared to the baseline one period model, the dynamic setting allows me to investigate the interaction of econmic reasons that lead individuals to postpone children and and natural decreases in fecundity by age that jointly result in involuntary childlessness. The structural results on fertility postponement are furthermore in line with much of the reduced form literature on the relationship between fertility choices and labor market outcomes. See for example Bertrand, Goldin, and Katz (2010), Wood, Corcoran, and Courant (1993), Budig and England (2001) or Lundborg, Plug, and Rasmussen (2017) for labor market consequences of childbirth, or Miller (2011) and Herr (2016) for the effects of postponement of children on labor market outcomes.

The remainder of the paper is structured in the following way: Section 2 motivates the research by illustrating the importance of both margins of fertility and discussing some distinct empirical facts from the German Microcensus. Section 3 introduces the theoretical model. Section 4 describes the data, estimation strategy and results. Counterfactual policy simulations are provided in Section 5 and Section 6 concludes.

2 Motivation

2.1 Historic Development in Germany

Germany's remarkable demographic development during the last years results from significant changes in both the extensive (decision to become a mother) and the intensive (number of children conditional on being a mother) margin of fertility. This is illustrated in Figure 1, which plots the historic development of both margins of fertility by focusing on cohorts of German women born between 1933 and 1966.[5] Overall, Germany experienced an increase in the rate of childless women and a decrease in the average number of children per mother. This development can broadly be separated in two distinct phases.

In the early phase (birth cohorts from 1933 to 1945, regular dashed line), childlessness rates remained relatively constant while the average number of children per mother decreased from

[5]Birth cohorts marked in red are used for model identification. Figure A.1 in the Appendix plots the extensive and intensive margin of fertility by birth cohort for different broad levels of education categories. The pattern observed in Figure 1 remains relatively unchanged when splitting up birth cohorts by educational background of the women.

about 2.2 to 1.8. This phenomenon is in line with the theory of the demographic transition[6], which phased out at approximately that time in Germany.[7] In the second phase (birth cohorts after 1945, bold dashed line), I observe a much more moderate decrease in the average number of children per mother but a strong increase in the childlessness rate from about 12.4% to 20.3%.

While the first phase is in line with the literature on fertility decrease, increases in (female) education and economic growth, as suggested by standard fertility theories (Becker and Barro (1988), Becker, Murphy, and Tamura (1990), Galor and Weil (2000), Lee (2003) or Doepke (2004)), this is not the case for the rapid increase in childlessness during the second phase, which still remains a puzzle.

2.2 Cross-sectional Evidence for Germany

Figure 2 provides a cross-sectional analysis of birth cohorts in the 2008 and 2012 waves of the German Microcensus. The 2008 and 2012 waves of the German Microcensus are the only waves that include a question on completed fertility. I restrict the sample to individuals where I can infer the timing of childbirth. Years of education are assigned to secondary, tertiary and/or vocational qualification.[8] The birth cohorts (1960-1966) are marked red in Figure 1. Several stylized facts about fertility and marriage patterns in Germany emerge.

Empirical Fact 1 - Fertility until Age 30: Panel (I) of Figure 2 plots the number of children born to women until age 30 who have at least one child during their lifetime against years of education. This represents the intensive margin of fertility, namely the decision on the number of children conditional on having at least one child, for model period[9] 1. The relationship between education and the number of children born before age 30 is downward sloping for both married (blue) and single women (red). Across all education groups, married women have on average a higher number of children than unmarried women.

Empirical Fact 2 - Fertility after Age 30: Panel (II) of Figure 2 plots the number of children born to women after age 30 who have at least one child during their lifetime against years

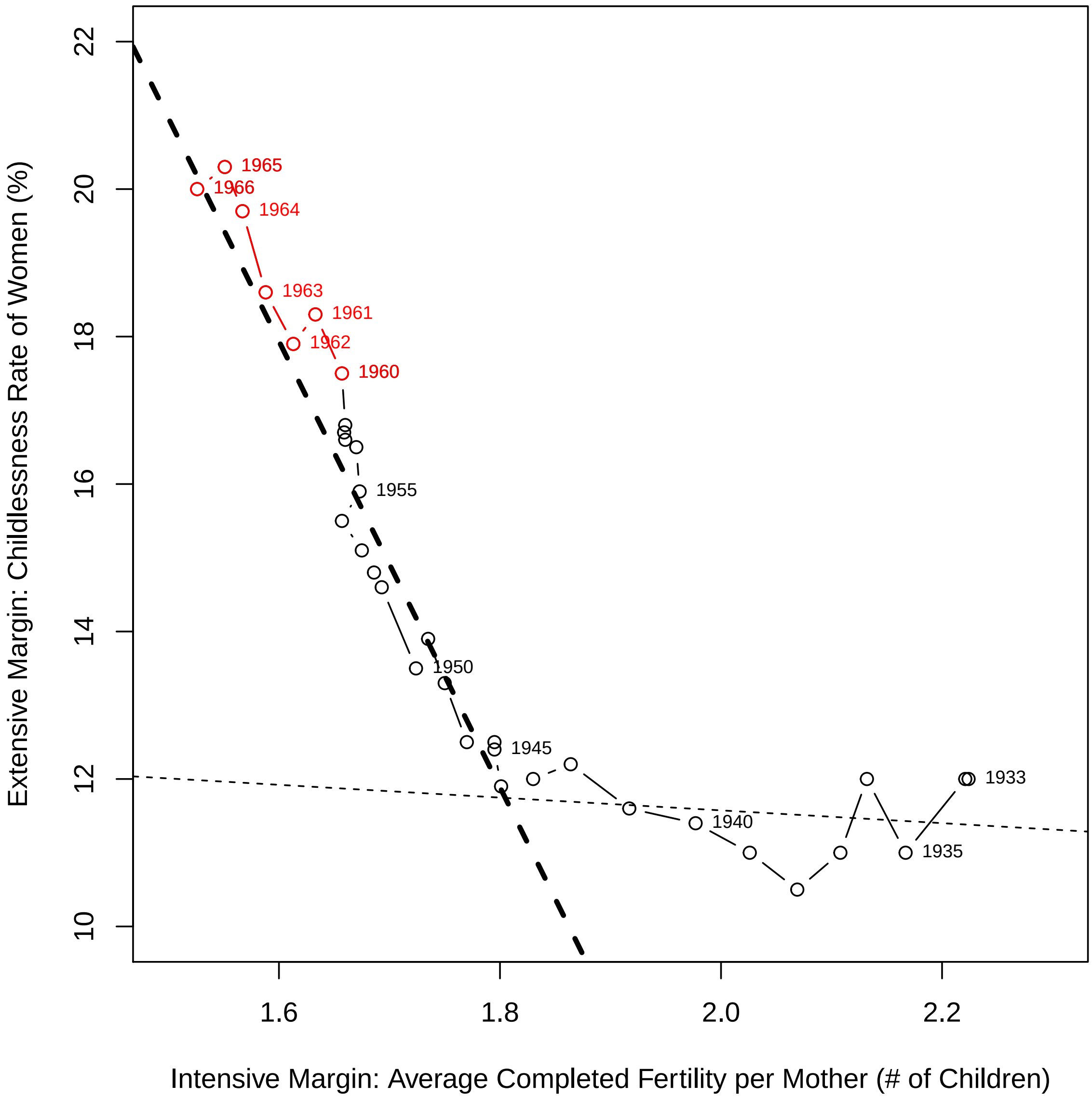
[6]The deliberate reduction in fertility and the increase in human capital investment into children (Galor and Weil (2000), Galor (2011)).

[7]Knodel (1974) dates the onset of the demographic transition for various regions (and different definitions of the onset) in Germany from 1871 to 1939.

[8]For information regarding data and methods used, see chapter 4.1.

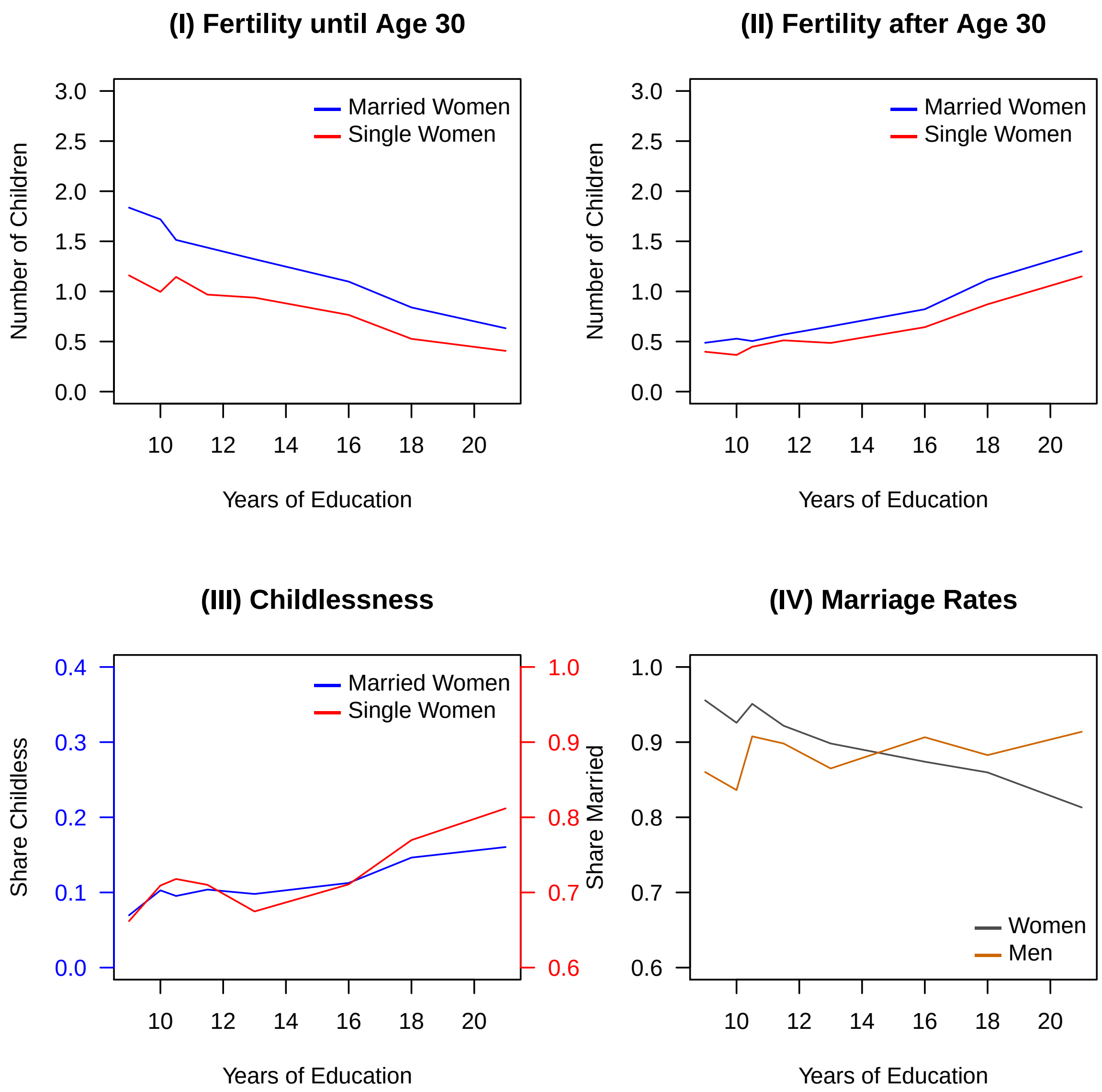
[9]Model period 1 refers to individuals until age 30.

Figure 1: Fertility along the Intensive and Extensive Margin



Notes: Childlessness (y-axis) is defined as the share of the female population that remains without children by age 45. Average Completed Fertility (x-axis) is the total fertility of all women above age 45. Birth cohorts used for estimation in the empirical part of this paper are marked red. *Data*: German Microcensus, survey years 2008 & 2012, own calculations.

Figure 2: Facts from the 2008 & 2012 German Microcensus



Notes: (I) Fertility of mothers until age 30 for married (blue) and single (red) women for different education groups. (II) Fertility of mothers after age 30 for married (blue) and single (red) women for different education groups. (III) Childlessness rate for married (blue, black y-axis on the left) and single (red, red y-axis on the right) women for different education groups. (IV) Marriage rates for women (gray) and men (orange) for different education groups. *Data*: German Microcensus, survey years 2008 & 2012, own calculations.

of education. This is the intensive margin of fertility for model period[10] 2. The relationship between education and the number of children born after age 30 is upward sloping for both married (blue) and single women (red). Similar to the intensive margin for model period 1, married women have on average a higher number of children than unmarried women for model period 2.

Empirical fact 1 and empirical fact 2 jointly indicate the postponement of having children for higher educated women. While women with a relatively low level of education have their children relatively early in life, highly educated women choose to have children later. This can be observed for both married and single women.

Empirical Fact 3 - Increasing Childlessness: Panel (III) plots the share of women who never become mothers by years of education. This represents the extensive margin of fertility, namely the decision to become a mother and have at least one child. The relationship between education and childlessness is upward sloping for both married (blue) and single (red) women. Between 67 and 80 % of single women remain childless. Childlessness rates of married women more than double from less than 8% for women with 9 years of education to almost 18% for women with a PhD.

Empirical Fact 4 - Marriage Patterns: Panel (IV) plots marriage rates for women (gray) and men (orange) by their respective education level. The relationship between education and marriage rates for women is downward sloping, indicating that women with a higher level of education are less likely to get married. The same relationship for men is upward sloping, indicating that men with a higher education level are more likely to get married.

2.3 Fertility and Childlessness across Countries

Low fertility rates and high levels of childlessness are not confined to Germany. As a matter of fact, low fertility rates and high levels of childlessness have become a common phenomenon in many countries, both developed and developing. Table A.1 in the appendix provides an overview of total fertility rates and childlessness for a sample of OECD and developing countries.

[10]Model period 2 refers to individuals above age 30 and until age 45.

Germany serves as an exceptionally good example for this phenomenon as it is among the countries with the lowest total fertility rate and highest childlessness rate. Moreover, Germany is composed of regions that belonged to different states until 1990, GDR (German Democratic Republic; East Germany) and FRG (Federal Republic of Germany; West Germany). Both countries had very different approaches to providing publicly available childcare and to encourage female labor force participation.

3 Model

In order to capture postponement and childlessness in a structural model, I expand the model by Baudin, De La Croix, and Gobbi (2015) to a three-period model.[11] Individuals face a trade-off between accumulating experience during period 1 and a lower likelihood of conception in period 2. Conception in period 1 is more likely, but also costlier in terms of foregone wage growth.[12] The model aims to capture the very basic idea that (female) fecundity decreases with age. In a three-period model, this is reflected by a higher rate of individuals who are unable to conceive for biological reasons. Lastly, the model captures negative wage penalties after longer times of part-time employment or non-employment due to time taken off for childcare.[13]

Decreases in biological fecundity in the three-period model are captured by a decreasing likelihood to conceive over periods.[14] For the remainder of the paper, "sterility" refers to the inability to conceive children in any period, and "infertility" refers to the inability to conceive children from period 2 onward. In period 3, all women are beyond of their reproductive age.

[11] Baudin, De La Croix, and Gobbi (2015) build a model explaining childlessness and fertility conditional on having children in a one-period setting. Childlessness can occur due to biological sterility and economic factors. By additionally adding the timing of children, I expand the model to also include strategic postponement of children for economic reasons. In combination with a naturally decreasing fecundity over time, postponement of children constitutes an additional channel for unintended childlessness.

[12] Similar to Baudin, De La Croix, and Gobbi (2015), the model abstracts from unwanted births. Studies on unwanted births place the magnitude in the order between 5% and 8.5% of all births in the US (Mosher, Jones, and Abma (2012) or Bumpass and Westoff (1970)). Since unwanted births are concerning mainly least educated women, I exclude all individuals without any educational background from the analysis. This also partly tackles the issue of reverse causality when women drop out of education because they become pregnant.

[13] By focusing on never married (single) and always married (married) individuals, the model abstracts from the risk of marriage failure. I am, however, currently working on an extention of this model that will incorporate divorce riskand endogenous divorce decisions.

[14] Notes on terminology: The realized number of children is referred to as "fertility". "Fecundity" refers to the biological ability to have children. Some individuals are born sterile. Over time, the biological ability to produce children decreases and more individuals become sterile. For a clear distinction and to avoid confusion, I introduce the terms "sterility" and "infertility".

The model assumes that everyone who is willing to have children and is not biologically sterile or infertile can have them in period 1 and 2.[15]

The sequence of events of the model is illustrated in Figure 3: In period 1, before fecundity shocks in period 1 are realized, women and men are matched with a potential partner of the opposite gender and have to make their decision on marriage. During the matching process, the share $\omega \in [0, 1]$ of individuals will be matched randomly with a potential partner across all education groups. The remaining share $(1 - \omega)$ is matched with someone within the individuals' own education group. The information available to them is gender, the education level of both partners and the non-labor income of both partners. This allows them to calculate the expected wages and thus expected gains from marriage.

The decision to get married is a non-cooperative decision on whether an individual will enter marriage.[16] Once marriage is entered both spouses behave cooperatively within. Individuals make the decision on entering marriage by calculating their gains from collective cooperative behavior under marriage and comparing their obtained utility to the outside option of single-hood. The model assumes that married couples and single women can have children, whereas single men can not.[17] Individuals who choose to stay single in period 1 remain single in all subsequent periods. Lifetime utility from marriage and under single-hood is calculated by backward induction, given the available information on expected labor income and fecundity. After the decision on fertility is made, individuals (or couples) try to have children. If having children is desired and biologically feasible, the desired number of children is realized. If children are desired but not biologically feasible, individuals learn about their (or their partner's) biological sterility.

At the end of period 2, single women and married couples learn about their biological infertility by not being able to have children if biologically infertile.[18] In the last period, there is no additional decision on fertility, as all women are beyond of their reproductive phase. However, individuals, who had children in both previous periods experience lower wages in the last period.

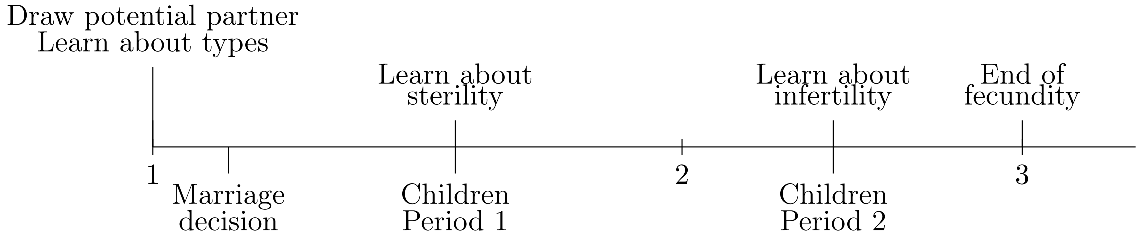
[15] Leridon (2004) shows that under normal conditions (e.g. without the additional use of assisted reproduction technologies) 75% of all women age 30 will conceive within 1 year and 91% within four years. Since the length of a period in the empirical part is 15 years, one can assume that conception can always be achieved when this is desired and biologically feasible.

[16] Alternatively, marriage could be described as "mutual coincidence of selfish wants".

[17] Women have both an earnings potential and reproductive capital (Low, 2017), whereas men are left with only their earnings potential.

[18] Biological infertility refers (slightly deviating from the medical usage of the term) to individuals who are unable to receive children during the later phase of what is usually considered the reproductive phase. The parameters for sterility and infertility are taken from the Hutterites and are assumed to be equally distributed across sex and education group. Values are taken from Tietze (1957).

Figure 3: Timeline of the Series of Events



Notes: Timeline of the series of events in the model. Numbers indicate the beginning of the respective period. Events depicted above the timeline are exogenous shocks or realizations of the agents. Events illustrated below the timeline are endogenous choices by the agents in the model. Sterility refers to the biological inability to conceive children in any period and is equally distributed between men and women. Infertility refers to the inability to conceive children from period 2 onward and only affects women. At the beginning of period 3 all individuals are no longer able to conceive.

3.1 Utility

The lifetime utility function of the individuals is independent of gender and marital status and defined by:

$$U^i = \sum_{t=1}^{t=3} \beta^{t-1}[\rho \, log(c_t^i) + (1-\rho) log(N_t + \nu)] \tag{1}$$

where i indicates individuals and t indicates periods. c_t^i is the consumption of individual i in period t . N_t is the number of children in the household in period t. This includes children born in time t and born in all previous periods and can thus be interpreted as the stock of children living in the household at time t. ν is a preference parameter which ensures that utility is well defined even when the number of children is zero. This allows to disentangle childlessness and completed fertility conditional on having children. The model assumes the utility flows from children to be constant across the child's age.[19] The stock of children is considered a public good within the household, consumption is private. Marriage in itself does not provide utility directly, but rather through economies of scale and sharing of child-rearing time between spouses.

3.2 Budget Constraints

Having children and taking care of them requires time that would otherwise be available for labor market activity.[20] The time cost required to raise children is split up in a fixed and a

[19] During the early years of the child, the utility flow may come from watching the child play and learn. Later, the utility flow may very well come from the child's achievements or simply the fact that the child is able to fix the WiFi/printer/smartphone when visiting.

[20] The model abstracts from leisure. Furthermore, there is no saving or lending in the baseline model. In theory, couples with consumption above $\hat{c}$ but below what is necessary to have children could save in order to be able

variable term. The fixed cost ($\eta_t \in [0, 1]$) has to be paid each period in which a woman gives birth to at least one child. I allow the fixed cost for motherhood to vary across periods to capture changes that make the transition to motherhood less costly over time. This picks up the effect of changes in the children production function over time, as well changes in the costs of becoming a mother that depends on the mothers age at the time of birth of the child. The variable cost ($\phi \in [0, 1]$) has to be paid per child in the period the child is born. This implies that the time spent on child-rearing per child is constant across education groups and time.[21]

Similar to Baudin, De La Croix, and Gobbi (2015) and Echevarria and Merlo (1999), the husband contributes $(1 - \alpha)$ to the time spent on raising the children. The remaining share $\alpha \in [0, 1]$ is contributed by the wife. This allows married women to have more children than single women and also makes married women less likely to remain childless. Furthermore, there is a public household good μ that has to be produced by the household, independent of household size. If married, this household good cost is produced jointly.[22]

Time available for work is reduced by the amount of time spent on children. For single women and men, the total time endowment is reduced by the amount $\delta^f \in [0, 1]$ and $\delta^m \in [0, 1]$, respectively. This cost of being single accounts for the time necessary for household chores that can not be shared with the spouse. δ^f is forced to be smaller than δ^m to account for the fact that women might receive help from others (e.g. their mothers or cohabiting partners) with raising the children, which is otherwise not captured in the model.[23]

There is a minimum consumption level ($\hat{c}$) required for women to be able to have children in a given period. The requirement of a minimum consumption level introduces a non-convexity in the budget constraint that is needed to generate the fertility-income relationship that discretely jumps from zero to one and then decreases in period 1 (as in Baudin, De La Croix, and Gobbi (2015)).

to be able to afford children later in life. Couples could also borrow money in order to have children early in life. Furthermore, savings that would be split up during a divorce could act as a marriage stabilizing device (similar to Lafortune and Low (2017)).

[21] Potentially, one can assume that more educated individuals spend less time with their children due to the larger opportunity costs. However, there are cases in which more educated individuals spend more time with their children in order to induce more human capital in them (Chiappori, Salane and Weis, 2017). Assuming ϕ to be constant across education groups constitutes a good combined effect and simplifies the model.

[22] Note that the public household good μ is produced using income rather than time. For married individuals, the public household good is produced before income is redistributed among spouses. See Section 3.4 for more details on the bargaining within marriage and resource allocation after bargaining.

[23] The penalty for single-hood also captures other benefits from marriages, such as joint taxation. A single-hood penalty that is smaller for women than for men would also capture relative advantages in home production that women may or may not have and taxation benefits that support single women/mothers.

Individuals have two sources of income - labor (w) and non-labor (a) income.[24] Labor income partly depends on individual choices. In the model, wages depend on gender, education and previous labor market experience. Individuals observe the wage for their given education level and are fully aware of their return to experience. They are furthermore aware that long periods of part-time employment can impact their future wage substantially. With that in mind, individuals choose how many children to have and how to space them across time. Non-labor income does not depend on any choices or educational background and is drawn from a log-normal distribution with mean $\kappa = ln(\overline{m}_a \cdot \overline{w}) - \frac{1}{2}\sigma_a^2$ and variance σ_a^2. $\overline{w}$ is defined as the mean wage of all women. Thus, $\overline{m}_a$ can be interpreted as the average ratio of labor to non-labor income of women. The non-labor income can be interpreted as the sum of unconditional transfers, gifts or bequests and is unconditional on education level or endogenous choices.

Formally, this translates into different per period budget constraints for single men (2), single women (3) and married couples (4), respectively.

$$b_t^{s,m}(c_t^m) = c_t^m - (1-\delta^m)w_t^m - a_t^m + \mu \leq 0 \tag{2}$$

$$b_t^{s,f}(c_t^f, n_t) = c_t^f + \eta_t w_t^f + n_t \phi w_t^f - (1-\delta^f)w_t^f - a_t^f + \mu \leq 0 \tag{3}$$

$$b_t^{w}(c_t^f, c_t^m, n_t) = c_t^f + c_t^m + \eta_t w_t^f + n_t \phi[\alpha w_t^m + (1-\alpha)w_t^f] - w_t^f - w_t^m - a_t^f - a_t^m + \mu \leq 0 \tag{4}$$

In addition to the budget constraint, women also face a pure time constraint in the production of children. Women who spend all their available time raising children in fertile periods are restricted in their per period fertility by the pure time constraint $\underline{n}_t^s = \frac{1-\delta^f-\eta_t}{\phi}$ for single women and $\underline{n}_t^w = \frac{1-\eta_t}{\alpha\phi}$ for married women. Married women can conceive a larger number of children as the husband helps raising the children and the cost of single-hood are absent.[25]

[24] Non-labor income is necessary to generate the negative aggregate fertility-income behavior in the first period when using a log specification for utility (see Jones, Schoonbroodt, and Tertilt (2010) and Baudin, De La Croix, and Gobbi (2015)).

[25] The resulting value is rounded (down) to the next integer as children are a discrete variable in the model. This makes the model both easier to compute as well as more realistic.

3.3 Wages and Labor Market Attachment

At the beginning of period 1, individuals learn about their expected wage for all periods conditional on their labor market participation. The realized wage is a function of their exogenous gender (gen) and education level (educ), as well as the endogenously determined previous labor market experience (exp):

$$w_t^i = f(gen, educ, exp) \tag{5}$$

If individuals choose to have children they lose labor market experience which negatively influences future wages. In addition to the loss of experience due to foregone labor market experience in every period, individuals also face a negative wage effect ($\epsilon \in [0, 1]$) if they spend both fertile periods raising children. The negative wage effect can be a result of discrimination or human capital depreciation due to long absence from full time employment.[26] The negative wage effect is shared between spouses according to their relative share in child-rearing, α for married women and (1 - α) for married men.

3.4 Marriage and Bargaining

At the beginning of period 1, individuals draw from the pool of available singles. Each individual draws a peer of own educational background with probability (1 - ω) and randomly from the pool of all available singles with probability ω (drawn from uniform). This ensures some level (1 - ω) of assortatively matched couples by educational background. There is no altruism within marriage.[27] However, there can be transfers within a household as a result of the bargaining process over fertility and consumption choices. Spouses renegotiate their choice variables at the beginning of each period according the cooperative collective decision model:[28]:

$$u(c_t^f, c_t^m, N_t) = \theta_t(w_t^f, w_t^m)u(c_t^f, N_t) + (1 - \theta_t(w_t^f, w_t^m)u(c_t^m, N_t) \tag{6}$$

[26] Long absence from full time employment can also increase the risk of unemployment, which may in addition affect the expected wage in the same way. However, the model does not distinguish those channels, but takes them as given and includes the effect on wages in individuals decision making.

[27] This assumption is in line with Chiappori (1988) and also made in Baudin, De La Croix, and Gobbi (2015).

[28] This follows Baudin, De La Croix, and Gobbi (2015). The alternative of Nash bargaining, where partners share the marriage surplus, requires some sort of shock to the quality of marriage in order to avoid marriage rates equal to 1. While something of that sort is possible in theory, this model assumes a cooperative collective decision model for simplicity.

where $\theta \in [0, 1]$ is the wife's bargaining parameter, which itself is defined as:

$$\theta(w_t^f, w_t^m) = \frac{1}{2}\underline{\theta} + (1 - \underline{\theta})\frac{w_t^f}{w_t^f + w_t^m} \tag{7}$$

The first part of the bargaining parameter $\underline{\theta}$ is constant, whereas the second part $1 - \underline{\theta}$ varies with the relative income of the partner. This captures the fact that women, regardless of their relative income, always have some minimum level of bargaining power in the marriage.[29] If the parameter $\underline{\theta}$ takes the value of 1, then both spouses have the exact same bargaining power, irrespective of the relative wage they earn. When $\underline{\theta}$ takes the value 0, then only the relative wage they earn matters for the bargaining position within the marriage. For any given number of children, married individuals pool their financial resources and redistribute them according to the bargaining parameter θ.

When deciding about marriage formation both potential spouses evaluate the value functions for being single and being married and compare the expected obtained utilities. While both potential spouses do not know about their own and their partner's sterility, they take the potential sterility and expected wages for all periods into account. They calculate the expected value of marriage and being single.[30] Only if both agree that marriage is beneficial, they get married. If one of the partners decides not to marry, both remain single and behave optimally under single-hood. For tractability, individuals only have one single draw for a potential marriage partner. As a result, there is no option value of single-hood since there is no outside option of finding a potentially better partner in a subsequent period.

Marriage can be beneficial for several reasons: (i) it provides a higher time endowment as time costs for being single (δ^f and δ^m) are not endured; (ii) the cost for the public household good μ is shared;[31] (iii) women can reach a higher level of consumption for a given number of children as part of the husbands' income is transferred via the household bargaining; (iv) men can (in contrast to being single) enjoy their children and obtain utility from them; and (v) consequences of spacing children out over both periods are mitigated through transfers from the spouse and sharing of costs.

[29] Alternative specifications could use relative labor income (as in Iyigun and Walsh (2007)) or further include the non-labor income (as in Pollak (2005)) instead of the relative wage of both spouses.

[30] The expected values are calculated by weighting the optimization outcome under sterility (fertility) with the likelihood of being matched with someone who is biologically sterile (fertile), taking one's own potential sterility into account.

[31] A public good within the household is often used in the literature to create the incentive to form a couple.

Table 1: Value Functions

Value Functions for the Marriage Decision, t $\in \{1,2,3\}$	
$V^{s,m} \equiv \max U(\{c_t^m\}_{t=1}^{T=3}, 0,0,0)$ s.t. $\{b_t^m(c_t^m) \leq 0\}_{t=1}^{T=3}$	Single Men
$V^{s,f} \equiv \max U(\{c_t^f\}_{t=1}^{T=3}, \{N_t\}_{t=1}^{T=3})$ s.t. $\{b_t^f(c_t^f, n_t) \leq 0\}_{t=1}^{T=3}$	Single Fertile Women
$\tilde{V}^{s,f} \equiv \max U(\{c_t^f\}_{t=1}^{T=3}, 0,0,0)$ s.t. $b_t^f(c_t^f) \leq 0\}_{t=1}^{T=3}$	Single Sterile Women
$\bar{V}^{s,f} \equiv \max U(\{c_t^f\}_{t=1}^{T=3}, N_1, N_1, N_1)$ s.t. $\{b_t^f(c_t^f, n_t) \leq 0\}_{t=1}^{T=3}$	Single Infertile Women
$V^{w,i} \equiv U(\{c_t^i\}_{t=1}^{T=3}, \{N_t\}_{t=1}^{T=3})$, where $\{c_t^f, c_t^m, n_t\}_{t=1}^{T=3} = \text{argmax } U(\{c_t^f\}_{t=1}^{T=3}, \{c_t^m\}_{t=1}^{T=3}, \{N_t\}_{t=1}^{T=3})$ s.t. $\{b_t(c_t^f, c_t^m, n_t) \leq 0\}_{t=1}^{T=3}$	Married & Fertile
$\tilde{V}^{w,i} \equiv U(\{c_t^i\}_{t=1}^{T=3}, 0,0,0)$, where $\{c_t^f, c_t^m, 0,0,0\}_{t=1}^{T=3} = \text{argmax } U(\{c_t^f\}_{t=1}^{T=3}, \{c_t^m\}_{t=1}^{T=3}, \{N_t\}_{t=1}^{T=3})$ s.t. $\{b_t(c_t^f, c_t^m, 0,0,0) \leq 0\}_{t=1}^{T=3}$	Married & Sterile
$\bar{V}^{w,i} \equiv U(\{c_t^i\}_{t=1}^{T=3}, N_1, N_1, N_1)$, where $\{c_t^f, c_t^m, n_1, 0, 0\}_{t=1}^{T=3} = \text{argmax } U(\{c_t^f\}_{t=1}^{T=3}, \{c_t^m\}_{t=1}^{T=3}, \{N_t\}_{t=1}^{T=3})$ s.t. $\{b_t(c_t^f, c_t^m, n_1, 0, 0) \leq 0\}_{t=1}^{T=3}$	Married & Infertile

Notes: All relevant function values are being evaluated before the individuals make their choice on marriage. Women are only potentially fertile in period 1 and period 2.

3.5 Value Functions and Marriage Decision

Before deciding on marriage formation, individuals calculate their expected utility of marriage and single-hood. In order to do this, individuals evaluate value functions for different potential states they could be in. These states depend on gender (women, men), marital status (married, single) and biological fecundity (sterile, infertile, fertile). The different value functions for men and women are displayed in Table 1. Single men are not able to have children and do not care about sterility or infertility. All other combinations of marriage status and gender (single women, married women, married men) care about infertility and sterility and evaluate the corresponding value functions. Once these value functions are evaluated, the individual chooses the regime that provides most utility.

Marriage occurs if it is beneficial for both partners, which formally means that:

$$(\zeta_f + (1-\zeta_f)\zeta_m)\tilde{V}^{w,i} + (\xi_f(1-\xi_m-\zeta_m) + \xi_m(1-\zeta_f))\bar{V}^{w,i} + (1-\zeta_f-\xi_f)(1-\zeta_m-\xi_m)V^{w,i} \tag{8}$$

is larger than

$$\zeta_f \tilde{V}^{s,f} + \xi_f \bar{V}^{s,f} + (1 - \zeta_f - \xi_f) V^{s,f} \tag{9}$$

and

$$V^{s,m} \tag{10}$$

$\tilde{V}$, $\bar{V}$ and V denote the value of being sterile, infertile and fertile for status $\in (single, married)$ and gender $\in (women, men)$. ζ_i and ξ_i are parameters for sterility and infertility, respectively. Biological sterility and infertility are assumed to be equally distributed across education levels.

Women calculate the value of being married (Equation 8) and compare it to the value of single-hood (Equation 9). Men compare the value of being married (Equation 8) with the value of being single (Equation 10). Both individual decisions are independent and there are no general equilibrium effects as there is only a single draw for a potential marriage partner in the model.

4 Empirical Analysis

The estimation strategy fixes some parameters of the model and estimates the remaining parameters with a minimum distance estimation technique using Powell's UOBYQA algorithm. A detailed explanation of the identification of the remaining model parameter can be found in section A.9 in the Appendix.

The values for biological sterility and infertility are taken from the Hutterites[32], on whom a number of studies on fecundity exist. According to Tietze (1957), sterility is observed for 2.4% of couples. An additional 8.6% of couples are unable to bear any children after the age of 30. Following Baudin, De La Croix, and Gobbi (2015), sterility is split equally among men and women and set at 1.21%. The decrease in fecundity (8.6%, referred to as "infertility") is attributed exclusively to decreases in female fecundity. Both biological components of fecundity are assumed to be equally distributed across education groups and marital status.

Wages are estimated as described in section 4.2. I set the bargaining parameter $\underline{\theta}$ to 1. This reflects an equal bargaining weight between men and women that does not depend on the

[32] Hutterites are a ethnoreligious group, similar to Amish or Monnonites. They are part of a christian movement that originated in the radical reformation in the 16th century. Today, most Hutterites live in North America.

relative wage.[33] Following the specification of the utility function in Baudin, De La Croix, and Gobbi (2015), I set the preference parameter ρ to 0.5.

4.1 Empirical Moments

I obtain empirical moments from the pooled 2008 and 2012 waves of the German Microcensus. The German Microcensus is an annual survey that yields representative statistics on the German population and labor force. Data access is provided by the Research data center (FDZ) of the statistical offices of the German federal states. The Microcensus samples 1% of all persons legally residing in Germany. It is the largest household survey in Europe. Participation is mandatory[34] and only a subset of questions can be answered on a voluntary basis. Typically, one household member responds to the survey for all individuals living in the household, including the spouse and children. The survey program of the German Microcensus consists of a set of core questions that remains unchanged in each wave, covering general socio-demographic characteristics like marital status, education, employment status, individual and household income, and many other things. Unfortunately, only the 2008 and 2012 waves of the German Microcensus entail a question on the completed fertility of women, while all other waves only ask for the number of children (not distinguishing from own biological and other) at different age groups currently present in the household.

I exclude women under the age of 45 from the data to observe completed fertility. To further correctly identify women who gave birth before they were 30 years of age, I make two assumptions. The first one is that children live with their parents until age 18. This is supported by the fact that, from a legal perspective, children under the age of 18 are not allowed to sign legally binding contracts such as rental contracts for an apartment without parental consent. The second one is that in case of divorce and re-marriage there is no systematic trend in the selection of a partner by education. This is necessary because remarried women are indistinguishable from only once married women in the data. On the basis of these two assumptions, the moments for identification per education group can be constructed. I subtract the children currently present in the household that were born after age 30 from the completed fertility. This separation gives me children born before and after age 30. Unfortunately, this reduces the sample further as now all mothers over the age of 48 (30 + 18) have to be excluded from the analysis.

[33]I thank David De La Croix for this helpful suggestion to reduce the estimated parameter space.
[34]According to the German Microcensus law, non-response may be fined.

For the baseline results, both waves of the German Microcensus are used in order to maximize the number of observations per cell. Furthermore, I perform a sub-sample analysis for an East-West split and for both waves of the Microcensus separately. I construct the years of education by assigning years of education to individual degrees earned. Then I sum up those years of education across the individuals secondary and tertiary degree, if applicable. The year value assignment to secondary, tertiary and vocational degrees follows the standard of the German Socioeconomic Panel (GSOEP) and is displayed in Table A.2 in the Appendix. All statistics of the observed individuals are weighted by the official sample weights provided by the German Microcensus.

This results in a total of 64 (8 moment dimensions and 8 education groups per moment dimension) means and the corresponding standard deviations that are available as moments for model parameter identification. The moment dimensions are childlessness (for single and married women), children before age 30 (for single and married women), children after age 30 (for single and married women) and marriages rates (for women and men). Education groups (9, 10, 10.5, 11.5, 13, 16, 18 and 21) are constructed to always include a sufficiently high number of observations per cell as well as to reflect population groups with a roughly equivalent educational background.

4.2 Wages

In the model, education and gender are exogenous and known before any of the decisions of the individuals are made. Labor market participation is, in every period, a choice variable.[35] I estimate the return on education and experience using the 2015 wave of the German Socioeconomic Panel (GSOEP) and compute wages based on the results as model inputs. The GSOEP provides separate measures for labor market participation depending on full-time or part-time employment.[36] I add both those measures and weight the part time employment by the number of hours worked relative to full time employment. In addition, the GSOEP also provides detailed information on education (see Table A.2 for translation from educational degrees to years of education). The estimation includes an intercept, a linear gender dummy (*gen*), education (*educ*) and labor market experience (*exp*). Education and experience are estimated using a third order

[35] Technically speaking, individuals choose their time spent on reproductive activities and thereby determine their labor market activity. However, individuals are fully aware of the time cost of raising children and implicitly choose fertility and labor market activity simultaneously.

[36] I restrict the sample to individuals who were always employed, either part or full time.

polynomial to pick up non-linearities in the development of wages.[37] Table A.4 in the Appendix provides the results of the wage regression.

$$ln(wage) = \beta_0 + \beta_1 gen + \beta_2 educ + \beta_3 educ^2 + \beta_4 educ^3 + \beta_5 exp + \beta_6 exp^2 + \beta_7 exp^3 \tag{11}$$

4.3 Minimum Distance Estimation

The model is estimated by a minimum distance procedure of the following form:

$$f(p) = [d - s(p)][W][d - s(p)]', \tag{12}$$

where p is the vector of parameters, d is the vector of empirical moments and $s(p)$ is the vector of simulated moments, which depend on the model parameters. The weighting matrix W contains $1/var(d)$ on the main diagonal, thus putting a higher weight on more precise moments relative to less precise moments.

I set the parameters for wages (depending on education and experience) based on the estimation result of Section 4.2. The wage of individuals is normalized to the wage of a married male with a PhD who contributed all his time to work.[38] The mean (female) wage used for the estimation of non-labor income is taken from the same dataset. The bargaining weight $\underline{\theta}$ is set to 1 (reflecting equal bargaining power of both men and women), the elasticity of the utility function is set to 0.5 to comply with Baudin, De La Croix, and Gobbi (2015). Natural rates for sterility and infertility for men and women are taken from Tietze (1957). The remaining 14 parameters (see: Table 2) are estimated using the minimum distance procedure. Wages in period 1 are further scaled in order to account for the longer working period of lower educated in comparison to individuals who spend more time in education.

The objective function is minimized in three steps to reduce the time required for estimation. First, an initial grid of 500,000 random grid points is evaluated in order to obtain adequate starting values for the optimization routines. Then, a genetic algorithm is used to obtain a

[37] I deflate net wage using the CPI with base year 2011. Reported net wages below EUR 1 are excluded as they are unrealistic.Descriptive statistics of the relevant variables are displayed in Table A.3 in the Appendix.

[38] This is simply to obtain relative wages. Married men, who contributed all their time to work have the highest labor income.

rough[39] vector of parameter values. Once the rough region of the global maximum is identified, I use Powell's UOBYQA algorithm to obtain the final results.

All optimization routine steps are performed under R version 3.5.1 with 10,000 observations (matched potential couples) per education group. A detailed description of the optimization routine of Powell can be found in Powell (2002). Standard errors are obtained in a bootstrapping style fashion. The optimization routine is performed for a smaller simulated sample size (10% sample) across various different (n = 500) random number seeds. Rather than drawing repeatedly from the same sample - as standard bootstrapping is performed - this approach samples from different populations to ensure that the parameter values are not a result of a specific drawn sample. The restrictions imposed by this approach are thus more restrictive compared to drawing sub-samples repeatedly from the same sample.

4.4 Estimation Results

4.4.1 Goodness of Fit

The model fit is illustrated in Figure 4. Empirical moments are depicted by solid lines. Simulated model moments are illustrated by dashed lines. The model performs reasonably well in terms of childlessness and fertility patterns for both married and single individuals. Section A.4 in the Appendix provides an overview over the normalized differences between the model and data moments along all model dimensions.

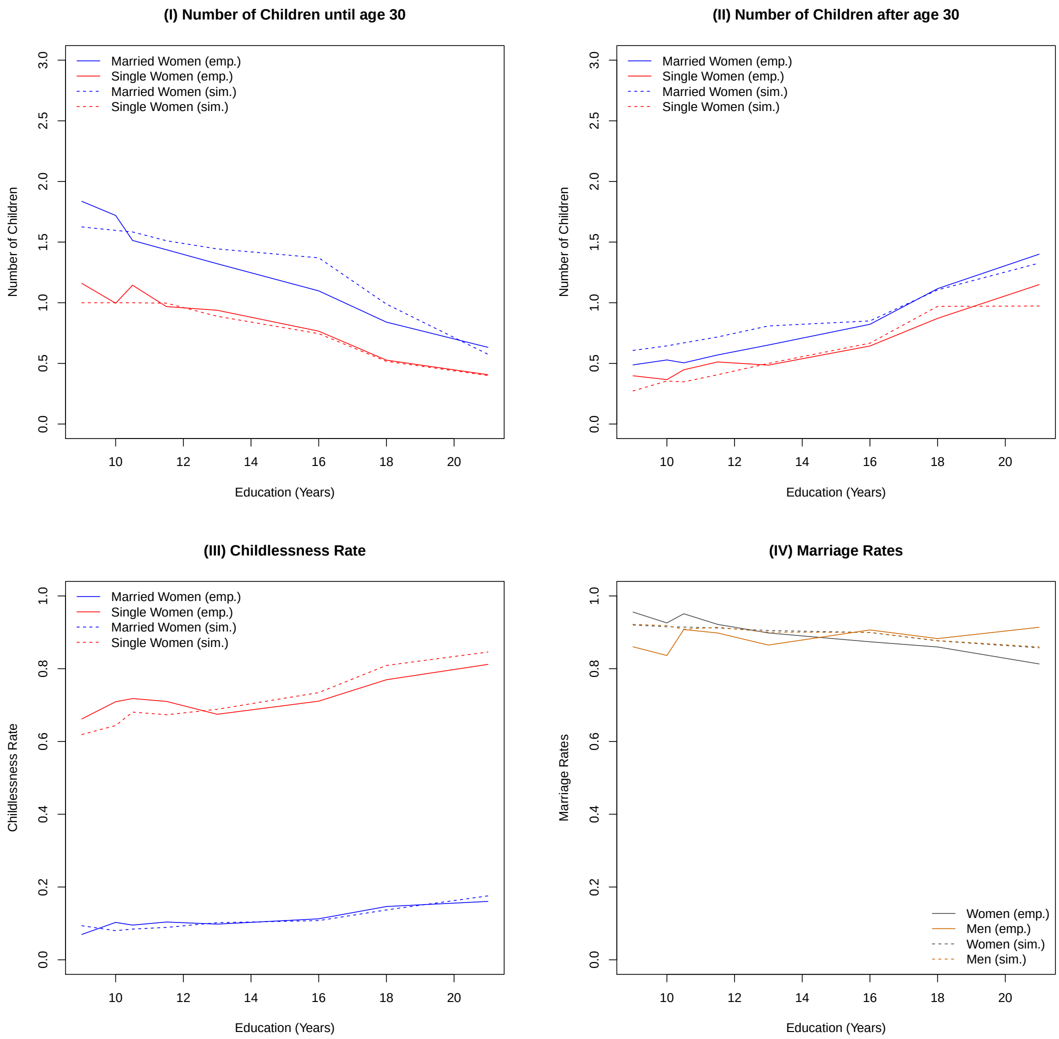
The fertility patterns (Sub-figures (I) and (II) of Figure 4) are captured very well for single women for both periods. For married women, the model predicts slightly higher fertility rates for medium educated women in the early life phase and women until 16 years of education after age 30. Sub-figure (III) of Figure 4 shows the childlessness rate for married (blue) and single (red) women by education group, which are closely captured by the model.

The model does a fairly well job capturing the levels of marriages rates (Sub-figure (III) of Figure 4). In absence of many aspects that drive marriage formation are absent of the model[40], the model fails to capture the slope for marriage rates. However, normalized differences indicate a relatively good model fit, compared with the other model dimensions.

[39] The generic algorithm is a stochastic optimization method for finding global maxima. In order to save time, the optimization routine is performed until the optimization converges. Once the optimization converged, a more systematic local optimization routine is performed.

[40] Most prominently: Love

Figure 4: Model Fit



Notes: Internal fit of the simulated model. Lines are empirical moments, dashed lines are simulation results. (I) Completed Fertility for married (blue) and single (red) women for different educational groups. (II) Childlessness rate for married (blue) and single (red) women for different education groups. (III) Fertility of mothers until age 30 for married (blue) and single (red) women for different education groups. (IV) Fertility of mothers after age 30 for married (blue) and single (red) women for different education groups. (V) Marriage rates for women (gray) and men (orange) for different education groups. (VI) Divorce rates for women (gray) and men (orange) for different education groups. *Data*: German Microcensus, survey years 2008 & 2012, own calculations.

4.4.2 Parameter Values

The estimated structural parameters are reported in Table 2. I calculate the standard errors by estimating the model 500 times across different random number seeds for a 10% subset of simulated matched individuals. The discount factor β is estimated at 0.971, indicating very little discounting in the context of fertility planning. The estimated discount factor is roughly equivalent to a 0.2% annual discount rate.[41] The discount rate equivalent to an interest rate below the market rate on the capital market suggests that individuals are willing to save in period 1 in order to be able to afford children in period 2. The preference parameter (ν) is estimated to be 6.137.

On top of the cost of motherhood ($\eta_1 = 0.187$, $\eta_2 = 0.013$) women contribute the (slightly) larger share ($\alpha = 0.546$) of the variable time cost of children ($\phi = 0.620$). The estimated parameter α from Baudin, De La Croix, and Gobbi (2015) is very close to the α estimated here. However, in Baudin, De La Croix, and Gobbi (2015) the male partner also contributes to the fixed cost of becoming a parent, which results in a larger share of male participation. Comparing the total cost of children over the lifecycle indicates that both partners have a more equal share of the child-rearing for children born after the age of 30. This is due to the sharp decrease in the fixed costs of becoming a mother. In period 1, married women contribute 65.1% of the total child rearing time for the first child. This number decreases to 55.5% for married women in period 2. The negative wage effect of spacing children across both periods ϵ is estimated at 62%.

The time costs of single-hood δ^f and δ^m are estimated at 0.106 and 0.321, for women and men respectively. Thus, single women loose 10.6% of their available time per period (time is normalized to 1) for being single. In addition to the cost of single hood, single women also face the full cost of the public household good ($\mu = 0.677$), while married women share this cost with their spouse. The minimum consumption level ($\hat{c}$), after which individuals decide to have children, is estimated at 0.461. These numbers together indicate that married women can have two children per period, whereas single women can only have one child per period at most. While these numbers seem very low, it is important to keep in mind that public childcare during the times when those women became mothers was largely unavailable and even school for children ended around noon. This forced many women/couples to spent a considerable amount of time with their children rather than working.

[41] Without savings/borrowing, the number of children is the only "asset" that can be inter-temporaly allocated. The "consumption" of children throughout the lifecycle is thus driving this very low discount rate.

The estimation results indicate that social benefits and other non-labor income ($\overline{m}_a$) roughly equals 1.3 times (standard deviation $\sigma_a = 0.513$) the average earnings of a female individual. While this seems to be rather high, Baudin, De La Croix, and Gobbi (2015) find their estimate to be around 1 in the context of the US, where social policies tend to be less generous than in Europe. A single woman of the lowest education level needs a non-labor income of 1.106 ($= \hat{c} + \mu - w(1 - \delta_f - \eta_1 - \phi)$, based on unrounded values) in period 1 not to be social sterile. In period 2, a single woman of the highest educational background needs a non-labor income of 0.947 ($= \hat{c} + \mu - w(1 - \delta_f - \eta_2 - \phi)$, based on unrounded values) not to end up childless.[42]

Germany has a relatively generous social system, supporting (single) mothers in financial distress. Nevertheless, the non-labor income is unreasonable large unless we include potential monetary flows from parents and biological fathers, who do not live with the single mother, to the interpretation. However, it is also important to keep in mind that this is an "optimal choice" model that abstracts from unwanted births. In reality, this may not always be given. When getting shocked with a "non-optimal" child[43], (single) women would probably end up consuming less than under optimality, investing less in their child (e.g. through ϕ), save on the public household good μ or do a combination of those things.

The percentage of individuals marrying someone with the same educational background is almost 60%. While this may be surprising in the context of other countries, this is very much within expectations for Germany, given the education system that puts children into certain academic achievement tracks from early age onward. Depending on individual competencies and achievements, German schoolchildren attend separate schools after the 4th oder 6th grade (depending on the federal state) already.

4.5 Decomposition of Childlessness

The model allows decomposing the reasons for childlessness into two main categories: Voluntary childlessness and involuntary childlessness. In the case of voluntary childlessness, individuals optimally decide not to have children. In the case of involuntary childlessness, individuals would like to have children, but are unable to have them. Voluntary childlessness again can be separated into two sub-categories: On the one hand, women (or couples) who would fall below

[42]The non-labor income is relative to the earnings of a married male with a PhD, since time is normalized to 1 for married and wages are normalized to the wage of a married male with a PhD. Furthermore, consumption above the minimum consumption level does not automatically result in children as those may not be optimal.
[43]Conditional on giving birth, as abortions are an option.

Table 2: Estimation Results

Parameter	Description	Estimate	S.E.
β	Discount factor	0.971	0.008
σ_a	Standard deviation of the log-normal distribution	0.513	0.003
ν	Preference parameter	6.137	0.013
μ	Good cost to be supported by a household	0.677	0.005
α	Fraction of child-rearing to be supported by women	0.546	0.003
ϕ	Time cost of having children	0.620	0.003
η_1	Fixed cost of children (period 1)	0.187	0.003
δ_m	Time cost for being single (men)	0.321	0.010
δ_f	Time cost for being single (women)	0.106	0.003
$\hat{c}$	Minimum consumption level for procreation	0.461	0.003
$\overline{m}_a$	Average ratio of non-labor income to labor income	1.327	0.005
ϵ	Wage effect of spacing children across time	0.617	0.008
η_2	Fixed cost of children (period 2)	0.013	0.003
ω	Share of randomly matched on marriage market	0.427	0.011

Note: Estimated parameters of the model. Parameters for wages and natural sterility and infertility are set. Standard errors are computed by bootstrapping across different random number seeds. Values rounded.

the minimum consumption level if having children are called "Constrained". The economic constraint renders women (or couples) socially sterile. On the other hand, women (or couples) can choose to have zero children due to high opportunity costs. The reason for their childlessness is "Optimal". Involuntary childlessness can also be separated into two sub-categories[44]: Some women (or couples) are unable to conceive children in any period for biological reasons. The reason for childlessness of sterile women (or couples) reflects "Sterility". Other women (or couples) are exposed to declining fecundity, namely infertility. They would have been able to have children in period 1, decide to postpone having children to period 2 for economic reasons and end up childless. The reason for childlessness of infertile women (or couples), who decide to postpone their fertility to period 2, is "Postponement".

Table 3 presents the reasons for childlessness (conditional on being childless) for all education groups estimated by the model. The results by marital status are reported in Table A.9 in the Appendix. Within each block, rows sum up to 1. My first finding is that the vast majority of childlessness in Germany is voluntary. Involuntary childlessness explains only about 21% to 26% of childlessness, depending on educational background. Within voluntary childlessness, the share of women, who remain childless due to social sterility ("Constrained"), is declining in education. This is a result of increasing wages. However, the higher wages of highly educated women also make those more likely to remain childless due to opportunity cost ("Optimal"). The

[44] I can also separate childlessness by the time individuals learn about the fact that they will be involuntarily childless. Results are reported in Table A.10 in the Appendix.

results for reasons of involuntary childlessness show large variation. The relative share of women who remain childless due to postponement of children increases monotonically from about 20% (women with basic secondary education, 9 years) to almost 70% for women with a PhD (21 years of education). Thus, "Postponement" is twice as important in explaining childlessness among highly educated women than "Sterility". When investigating the sub-sample of single women, the relative share of involuntary childlessness due to "Postponement" even exceeds 80% for highly educated women. The share of total childlessness within an education group that is a result of "Postponement" can be calculated by multiplying the share of "Involuntary" with the share of "Postponement". Depending on education, this share increases from 4.4% in the case of basic secondary education to 15.6% for women with a PhD. Similarly, the share of "Sterility" decreases from 11.6% to 7.2%. I obtain the aggregate effect on the population level by weighting those shares according to the relative size of the education groups in the population. "Postponement" explains 7.6% and "Sterility" explains 15.0% of total childlessness at the population level.

Table 3: Reasons for Childlessness (Baseline)

			Voluntary Childlessness		Involuntary Childlessness	
Education	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement
1	0.786	0.214	0.457	0.543	0.793	0.207
2	0.781	0.219	0.531	0.469	0.746	0.254
3	0.784	0.216	0.518	0.482	0.724	0.276
4	0.762	0.238	0.522	0.478	0.615	0.385
5	0.741	0.259	0.528	0.472	0.557	0.443
6	0.776	0.224	0.488	0.512	0.535	0.465
7	0.773	0.227	0.481	0.519	0.359	0.641
8	0.771	0.229	0.382	0.618	0.318	0.682

Note: Reasons for childlessness by women's education. Sample restricted to women/couples who are childless in baseline. Values within one line per sub-block add up to one. The blocks "Voluntary Childlessness" and "Involuntary Childlessness" contain the sub-groups of "Voluntary" and "Involuntary", respectively. Values rounded.

In the case of voluntary childlessness, the outcome is optimal from an individual's perspective. This is not the case for involuntary childlessness, which results in utility loss. The size of the loss in individual's utility depends on the type of involuntary childlessness, marital status as well as labor and non-labor income. In general, there are two counteracting effects. First, the loss in the number of children directly results in lower utility. Second, the time that is now available for market work (rather than child-rearing) results in more consumption, both directly via the supply of labor and indirectly via the return to experience that increases wages for following periods. I quantify the loss of utility (in terms of equivalent net present value consumption) for some illustrative examples of the following population groups: (i) a single sterile woman and (ii) a single infertile woman, (iii) a married couple exposed to sterility, (iv) a married couple exposed to infertility.

Single women require a sufficiently large non-labor income, to avoid social sterility and potentially become mothers. Depending on the relative size of labor and non-labor income those single women decide to have a child in period 1 or period 2. The first illustrative example is a single sterile woman with 16 years of education and a non-labor income 47.9% above the average. Optimally, such a woman would choose to have one child in period 1 and zero children in period 2. The change from having one child in period 1 to childlessness results in a loss of lifetime utility equivalent to 22.0% of net present value lifetime consumption. This effect is counteracted by increases in consumption as a result of higher labor market participation. This second effect closes the gap in individual's utility from 22.0% to 4.6% in equivalent net present value consumption. The total loss in utility increases with non-labor income as a higher labor income is needed to offset the loss in utility from having zero children. Increases in education, on the other hand, lower the final gap for a given non-labor income as a result of higher wages and larger returns to experience.

The second illustrative example is a single infertile woman with 16 years of education and a non-labor income 23.4% above the average. This woman would optimally wait until period 2 to have a child and benefit from larger wage growth in period 1. The loss in utility due to the transition from one child in period 2 to zero children is equivalent to a net present value lifetime consumption loss of 14.4%. The counteracting labor supply effect closes the gap in individual utility to 1.2% in equivalent net present value consumption. Compared to sterility, the total effect of infertility is substantially smaller as the loss in utility from the reduced number of children is only experienced for two instead of three periods. Similar to the case of sterility, the total loss in utility increases for small increases in non-labor income and decreases by educational background. Sufficiently large changes in non-labor income, however, will result in children being optimal in period 1 already.

Due to a higher number of children under optimal conditions, the effects of sterility and infertility are substantially larger for married couples. For a marriage in which both partners have 16 years of education, an average non-labor income and where (at least) one partner is biologically sterile, the loss in lifetime utility per person is equivalent to a present value lifetime consumption decrease of 62.1%. The labor supply effect decreases the loss in utility to 25.9% in equivalent consumption. Since married individuals pool their financial resources, this value is the same across genders. The total loss in utility increases with the non-labor income of both partners and decreases with the education. The effect of increases in education is not equal across both genders. Women contribute a larger share of child-rearing, which increases the effect size of the labor supply effect more for women than men.

The same married couple (both 16 years of education and average non-labor income) would experience a loss in total utility equivalent to 5.2% of net present value consumption per individual in the case of biological infertility. The effects are substantially smaller than for sterility, as the couple is only restricted in their period 2 fertility and can have the intended number of children in period 1. The effect of the loss in period 2 children is reduced by the labor supply effect from 21.0% to 5.2% in equivalent consumption.

4.6 Heterogeneity between East and West Germany

For the baseline results I use the pooled 2008 and 2012 waves of the German Microcensus, covering Germany in total. In this section, I estimate the model separately for East and West Germany to address (persistent) institutional differences between both former countries. Furthermore, I estimate the model separately for the 2008 and 2012 waves of the Microcensus. The model parameters are displayed in Table 4. For readability, the results, including standard errors, are reported in Table A.11 in the Appendix.

Overall, all subsets yield relatively similar results. This is in particular the case for the separate analyis of the 2008 and 2012 waves of the German Microcensus. There are, however, substantial[45] differences between East and West Germany.

There are three different channels through which the exposure to the German Democratic Republic (GDR, East Germany) could have affected fertility behavior for East German women.[46] First, government ideology could change the utility received from children. This would be captured in differences in the preference parameter ν. Second, women were expected to work and not take time off to raise children. Thus, staying at home to raise children could result in

[45] In the presence of generally very low standard errors in structural estimation, I refrain from using the term "significant" to avoid confusion.

[46] Presented in reverse order of magnitude/importance. However, I acknowledge that there are potentially more that are not captured by the model.

Table 4: Estimation Results for Subsamples

Parameter	Description	Baseline	West	East	2008	2012
β	Discount factor	0.971	0.954	0.964	0.971	0.994
σ_a	Standard deviation of the log-normal distribution	0.513	0.537	0.500	0.513	0.524
ν	Preference parameter	6.137	6.010	6.129	6.237	6.154
μ	Good cost to be supported by a household	0.677	0.689	0.658	0.677	0.678
α	Fraction of child-rearing to be supported by women	0.546	0.554	0.537	0.546	0.535
ϕ	Time cost of having children	0.620	0.617	0.600	0.620	0.623
η_1	Fixed cost of children (period 1)	0.187	0.198	0.074	0.187	0.192
δ_m	Time cost for being single (men)	0.321	0.346	0.345	0.321	0.331
δ_f	Time cost for being single (women)	0.106	0.105	0.157	0.106	0.103
$\hat{c}$	Minimum consumption level for procreation	0.461	0.417	0.445	0.461	0.462
$\overline{m}_a$	Average ratio of non-labor income to labor income	1.327	1.211	1.344	1.327	1.314
ϵ	Wage effect of spacing children across time	0.617	0.544	0.719	0.617	0.614
η_2	Fixed cost of children (period 2)	0.013	0.005	0.041	0.013	0.010
ω	Share of randomly matched on marriage market	0.427	0.498	0.452	0.427	0.428

Note: Estimated parameters of the model for different data subsets (West Germany, East Germany, 2008 Microcensus and 2012 Microcensus). Parameters for wages and natural sterility and infertility are set. For readability bootstrapped standard errors are reported in table A.11 in the appendix.

a higher wage penalty in East Germany compared to West Germany. Third, socialist ideology aimed to emancipate women in the labor market by providing largely available public childcare. In the model, this is captured by differences in the cost of children, either fixed (η_1, η_2) or variable (ϕ).

For the preference parameter for children, I find a difference of 0.119 between East and West Germany. Women (and couples) in East Germany obtain a larger utility already from having zero children. However, these differences are small compared to the parameter value (6.010 for West and 6.129 for East Germany). The small difference relative to the parameter value indicates that there are no large effects of government ideology on the preference for children between East and West Germany.[47] I find the effect of spacing children over both periods, a negative wage penalty, to be substantially larger in East Germany. Compared to 0.544 for West Germany, the parameter value increases by 32% to 0.719 in East Germany. This shows that there are larger negative effects of prolonged absence from the labor market in East compared to West Germany. The wage effect may be intensified by the fact that the late reproductive phase of the women in the sample starts around the time of the German Reunification. During this time, individuals in the East had to adapt to the market-based economy of West Germany, which made absence from the labor market even more costly as previously obtained human

[47]For a childless married West German women, where both spouses have 16 years of education and an average non-labor income, the effect of having the East German ν instead of the West German ν results in a utility increase that is equivalent to a 2.8% increase in net present value consumption.

capital depreciated faster.[48] All those effects jointly result in a 32% larger wage penalty for a long absence from the job market due to child-rearing for East compared to West Germany. For a more short-term microeconometric analysis of the consequences of the fall of the Berlin wall see Chevalier and Marie (2017), who find strong but short-lasting negative fertility responses in East Germany, in particular among higher educated women.

Finally, there is a remarkable difference between East and West Germany in the fixed costs of becoming a mother (η_1 and η_2). While the costs of becoming a mother are relatively constant for East Germany, it decreases substantially for West Germany and even surpasses East Germany. Differences in the variable cost of children (ϕ) are relatively small. Historically, East and West Germany had very different approached to public provision of childcare. While women in West Germany usually dropped out of the labor force for the time they raised their children, women in East Germany continued their career and could rely on largely available public childcare. In fact, the extent to which affordable public childcare was available in East Germany is often seen as a potential role model for West Germany, even today. For a more detailed investigation of the changes of the fixed cost of becoming a mother, a back-of-the-envelope difference-in-difference calculation of the time cost of the first child is performed in Table 5.

Table 5: Time Cost for First Child (Differences Analysis)

Time	West	East	*Difference*
Before Age 30	0.541	0.396	0.145
After Age 30	0.347	0.363	-0.016
Difference	0.194	0.033	0.161

Note: Full (fixed and variable) time cost of the first child for married women. Values are based on sub-sample estimation results for East and West Germany. Values rounded.

There are several potential reasons for the large decline in the fixed cost of becoming a mother over the lifecycle in West Germany: (i) Increasing efficiency due to age/experience, (ii) expansion of the public provision of childcare, or (iii) increasing support from parents, as those are more likely to reach retirement and are able to provide informal childcare. As a matter of fact, García-Morán and Kuehn (2017) document that some women/couples in Germany locate near their parents or in-laws for informal childcare support.

[48] An additional option can be higher unemployment risk as a result of long absence from the labor market. This effect would also be stronger in combination with the German Reunification.

Unfortunately, this simple calculation does not allow to disentangle the effects of the expansion of public childcare over the observed time from the effect of the provision of informal childcare by relatives, such as parents. However, under two assumptions the joined effect of informal provision of childcare and increases in the publicly availability of childcare can be calculated. First, age-related efficiency gains in the production of children developed in parallel in East and West Germany. Second, due to the large scale availability of public childcare the informal provision of childcare, informal childcare is not of major importance / less common in East Germany. The raw difference in the time required to raise the first child between the two periods is 0.194 for West Germany and 0.033 for East Germany. Attributing the 0.033 to the age effect, leaves a joint effect of 0.161 for increases in the provision of both public and informal childcare for West Germany. This equals 83% of the fixed cost of becoming a mother in period 1.

These differences in the costs of having children are also reflected in the reasons for childlessness in East and West Germany. Table 6 and tables A.12 and A.13 in the Appendix provide an overview over the reasons for childlessness by womens' education level. The left block contains the reasons for childlessness for West Germany, the right block for East Germany. The higher time costs of children in West Germany are a large factor for childlessness. The higher costs of children lead to a larger share of voluntary childlessness among most education groups in West Germany Within voluntary childlessness, "Constrained" is (apart from the very low educated) consistently of greater importance in West Germany. Within involuntary childlessness, "Postponement" is of larger importance in West Germany. This is a result of the larger drop in fixed time cost of becoming a mother between period 1 and period 2 for West Germany. Given the same return to experience, the very small difference in the fixed time cost of mother-hood does not trigger as much postponement of parenthood in East Germany.

Table 6: Reasons for Childlessness (West Germany vs. East Germany)

	West Germany						East Germany					
			Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness	
Education	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement
1	0.819	0.181	0.371	0.629	0.704	0.296	0.756	0.244	0.374	0.626	0.933	0.067
2	0.831	0.169	0.397	0.603	0.656	0.344	0.788	0.212	0.332	0.668	0.896	0.104
3	0.819	0.181	0.432	0.568	0.579	0.421	0.789	0.211	0.372	0.628	0.892	0.108
4	0.786	0.214	0.395	0.605	0.505	0.495	0.767	0.233	0.376	0.624	0.876	0.124
5	0.795	0.205	0.410	0.590	0.504	0.496	0.802	0.198	0.384	0.616	0.894	0.106
6	0.787	0.213	0.419	0.581	0.463	0.537	0.807	0.193	0.364	0.636	0.894	0.106
7	0.799	0.201	0.406	0.594	0.333	0.667	0.816	0.184	0.366	0.634	0.675	0.325
8	0.812	0.188	0.368	0.632	0.300	0.700	0.807	0.193	0.307	0.693	0.446	0.554

Note: Reasons for childlessness by women's education. Sample restricted to women/couples who are childless. Left block for West Germany, right block for East Germany. Values within one line per sub-block add up to one. The blocks "Voluntary Childlessness" and "Involuntary Childlessness" contain the sub-groups of "Voluntary" and "Involuntary", respectively. Values rounded.

5 Counterfactual Simulations

In this section, I use the estimated model parameters to simulate the impact of policy changes and labor market conditions on fertility along the intensive and extensive margin. I use the structural model to simulate the behavior for a sample of 10,000 (potential) couples per education group[49] for counterfactual underlying parameter values. In particular, I simulate changes in the availability of public childcare and changes in the wage penalty for spacing children across time. I make use of the previously obtained results for East and West Germany to simulate the counterfactual states for the implementation of the East German public childcare system and the East German wage penalty to West Germany. Furthermore, I assess how potential future increases in the wage penalty can be counteracted by expansion of public childcare. The model fit of the West German model is displayed in Table A.2 in the Appendix.

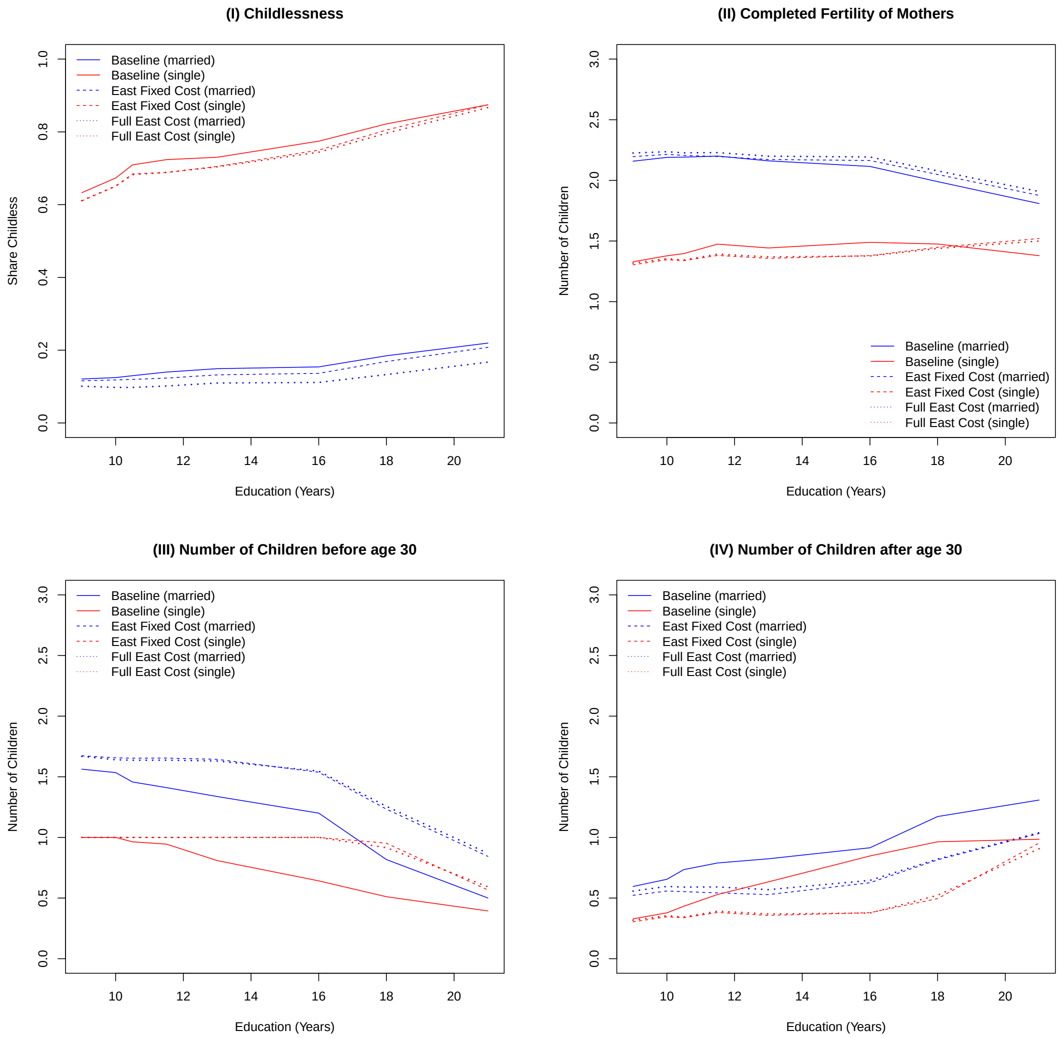
5.1 Public Provision of Childcare

For the first counterfactual experiment, I simulate a full application of the East German public provision of childcare to West Germany. I assume that everyone who desires publicly provided childcare is able to obtain it. I further assume that individuals always choose the cheapest childcare option. In period 1, this is the East German fixed (η_1) and variable (ϕ) cost of children. In period 2, this is the West German fixed (η_1) and East German variable (ϕ) cost of children. The results are illustrated in Figure 5 and tables A.14 and A.15 in the Appendix. The comparison of the counterfactual experiments with the empirical moments is illustrated in Figure A.3 in the Appendix. The solid line plots the baseline moments. The dashed line plots the results for the application of the fixed cost of motherhood (η_1). The dotted line plots the full application of both fixed (η_1 and variable (ϕ) cost of children.

For the sole implementation of the East German fixed cost of becoming a mother in period 1 (η_1, dashed line), I observe a lower number of childless single women for all education groups but the most highly educated. As a result of the changed composition, the completed fertility for single mothers of all but the most highly educated is lower. Most highly educated single women postpone motherhood to period 2, both in baseline and counterfactual. As a result, I observe very little differences in the rate of highly educated childless single women. However, those highly educated single women, who in counterfactual decide to have their children in

[49]With 8 education groups, this results in 80,000 potential couples.

Figure 5: Application of the East German Children Production Costs



Notes: Counterfactual Simulation - Simulating the application of the East German children production costs to West Germany. Lines are baseline estimation moments, dashed lines are simulation results for the application of the fixed cost (η_1) in period 1 only, dotted lines are the simulation results for the full application of the East German children production costs (η_1 & ϕ).

period 1 already, increase completed fertility. For married women, I find slightly lower rates of childlessness and higher rates of fertility across all education groups.

When additionally also applying the East German variable cost for children (ϕ), the rate of childlessness is lower for both married and single women across all education groups. For single women, in particular highly educated ones, I find lower rates of childlessness. The completed fertility of highly educated single women is slightly lower compared to the application of only the East German fixed cost of children. This is due to women's transition from single-hood to marriage. For married women, I observe a substantial lower degree of childlessness. The main reason for the differences between the application of only the fixed costs and the application of both fixed and variable costs is that the latter also affects the costs of children from the husbands' labor supply perspective. In the case of a sole reduction in the cost of becoming a mother, men are only affected via consumption and consumption transfers from/to their wife. This makes the childlessness of married women react stronger to changes in the variable cost of children (ϕ), both compared to single women and to only the application of the East German fixed cost of children in period 1 (η_1).

More striking than the differences in the completed fertility, are the differences in the postponement of children. In particular, the education level after which optimal postponement behavior starts increases to about 16 years of education for married women and 18 years of education for single women. The higher number of children in period 1 is offset by a lower number of children in period 2, resulting in little change in the completed fertility of mothers. I find relatively little differences for the shift in inter-temporal allocation of children between both counterfactual scenarios. However, the transition from baseline to counterfactual results in substantial inter-temporal allocation shifts for children.

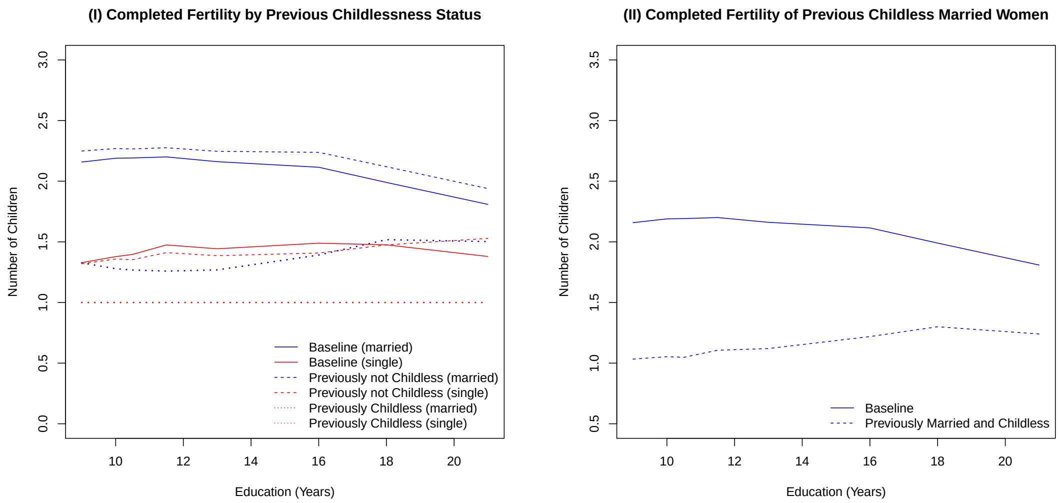
Next, I investigate the transition from childlessness to motherhood under the counterfactual scenario. I decompose the fertility rates of women, who have children in counterfactual, into "new" mothers and mothers who were already mothers in baseline. Sub-figure (I) of Figure 6 plots the completed fertility of mothers. The solid line plots the baseline results. Dashed lines illustrate the completed fertility of previously not childless women. Dotted lines illustrate the results for previously childless women. Single women are marked red, married women blue. I observe that previously married women who already had children in baseline display a slightly higher completed fertility following the reduction in childcare cost. Married women with children in counterfactual who were childless in baseline have a completed fertility between 1.3 and 1.5 children, depending on education. Those women exhibit a lower average number of children per mother (conditional on having children), but a higher overall number of children are born as they were previously childless. Compared to baseline, we observe lower completed fertility rates for most single women as a result of some women leaving single-hood into marriage. Single women who were childless at baseline but are single mothers now only have one child, independently of educational background. Single women are constrained in their per period fertility to one child, due to the time constraint. Thus, if previously childless single women decide to have children in one period only, they will automatically have exactly one child.

Sub-figure (II) of Figure 6 plots the completed fertility of women who are childless in baseline and married in both the baseline and the counterfactual. This comparison investigates only the impact of the lower costs of children for married women, excluding selection into marriage that changes the composition of the underlying population of married women. The solid line plots the baseline results. The dashed line illustrates mothers who were previously married and childless. I observe an upward sloping completed fertility pattern. If children are considered a normal good, decreases in the relative price, compared to other types of consumption, will result in a larger consumption share of children.

Lastly, I investigate how the full adoption of the East German cost of children affect the reasons for childlessness. The reasons for childlessness are reported in Table 7. I find that the lower fixed cost of becoming a mother causes less postponement of children to period 2. This is reflected in the lower relative share of "Postponement" as the reason for childlessness, compared the West German baseline results. Next, I focus on individuals who transition from one reason of childlessness in baseline to either being a parent or to another reason for childlessness in counterfactual.[50] The transition shares of previously childless women are displayed in Table 8. The reason for childlessness in baseline is reported in rows, the reason for childlessness in counterfactual in columns. Within each block, shares sum up to one. Individuals (or couples) not changing their status in childlessness are displayed on the diagonal. The largest movement, when using the full sample of previously childless women, is from optimal childlessness to not being childless. This effect is largely driven by married women. The effect size of the transition from constrained to not childless is substantially smaller in absolute terms. However, childlessness

[50] Application of both East German fixed cost of becoming a parent in period 1 (η_1) and variable cost of children (ϕ)

Figure 6: Transitions Out of Childlessness



Notes: Counterfactual Simulation - Simulating the application of the East German children production costs (η_1, & ϕ) to West Germany. The left figure plots the completed fertility of women by previous childlessness status. Regular lines indicate the baseline results, dashed lines plot previously not childless women and dotted lines plot previously childless women. Single women in the counterfactual simulation are illustrated in red, married women in blue. The right figure plots the completed fertility of women who are married in both baseline and counterfactual were childless in baseline. Regular lines plot the baseline results, dotted lines illustrate previously married childless women.

due to constrainedness is only a factor for single women in baseline. Weighting the share by the relative size of single compared to married women, effect sizes become roughly similar. Focusing only on individuals who change their status (either in childlessness or the reason for childlessness, right block of Table 8), I find that almost 60% of women/couples transition from "Optimal" to not being childless. The second largest group, with almost 30% of all transitions, switches from "Postponement" to not childless. Regarding transitions into involuntary childlessness, I find 1.3% of all transitions to transition to "Sterility" and 4.2% to transition to "Postponement."

Table 7: Reasons for Childlessness (East German η_1 / East German η_1 & ϕ)

	East German η_1						East German η_1 & ϕ					
			Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness	
Education	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement
1	0.842	0.158	0.364	0.636	0.837	0.163	0.813	0.187	0.407	0.593	0.809	0.191
2	0.858	0.142	0.391	0.609	0.820	0.180	0.832	0.168	0.451	0.549	0.790	0.210
3	0.858	0.142	0.426	0.574	0.800	0.200	0.839	0.161	0.489	0.511	0.807	0.193
4	0.851	0.149	0.393	0.607	0.805	0.195	0.821	0.179	0.454	0.546	0.784	0.216
5	0.856	0.144	0.408	0.592	0.810	0.190	0.827	0.173	0.474	0.526	0.763	0.237
6	0.848	0.152	0.419	0.581	0.718	0.282	0.823	0.177	0.486	0.514	0.708	0.292
7	0.839	0.161	0.408	0.592	0.449	0.551	0.813	0.187	0.485	0.515	0.476	0.524
8	0.833	0.167	0.369	0.631	0.351	0.649	0.800	0.200	0.432	0.568	0.347	0.653

Note: Reasons for childlessness by women's education. Sample restricted to women/couples who are childless in the counterfactual scenarios. Left block for the application of the East German η_1 to West Germany, right block for the application of the East German η_1 and ϕ to West Germany. Values within one line per sub-block add up to one. The blocks "Voluntary Childlessness" and "Involuntary Childlessness" contain the sub-groups of "Voluntary" and "Involuntary", respectively. Values rounded.

Summing up, both counterfactual simulations indicate that public provision of accessible childcare affects the timing of children much more than the final number of children per mother.

Table 8: Childlessness Transitions (East German η_1 & ϕ for West Germany)

		New Status (All)					New Status (Switchers)		
		Not Childless	Sterility	Postponement	Constrained	Optimal	Not Childless	Sterility	Postponement
Old Status	Sterility	0.000	0.092	0.000	0.000	0.000	0.000	0.000	0.000
	Postponement	0.057	0.000	0.046	0.000	0.000	0.298	0.000	0.000
	Constrained	0.012	0.000	0.000	0.309	0.000	0.061	0.002	0.000
	Optimal	0.112	0.002	0.008	0.000	0.363	0.585	0.011	0.042

Note: Transitions in the reason for childlessness. Sample restricted to women/couples who are childless in baseline. Old status refers to the reason for childlessness in baseline, new status in the counterfactual. "Switcher" is restricted to women/couples that change their status, either with respect to childlessness or the reason for childlessness. Values rounded.

As a result of the much lower costs for children in terms of foregone labor income and experience, a larger fraction of women/couples decides to have children earlier in life. This is counteracted by (almost equally) corresponding lower fertility rates after the age of 30. I find childlessness to decrease for all women, independent of marital status and education. Overall, about 19% of previously childless women change either their reason for childlessness or transition out of childlessness, with the largest share transitioning to parenthood. Calculating the completed cohort fertility for the counterfactual state, weighting the education groups by their respective share in the population, results in a completed cohort fertility of 1.737. This is equivalent to a 13.5% increase in the completed cohort fertility compared to the observed data[51] for the birth cohort of 1966. In the observed data for women born in 1966, the completed cohort fertility in Sweden is 31.0% above the one for Germany. In the counterfactual state, this difference would be reduced by half to 15.4%.

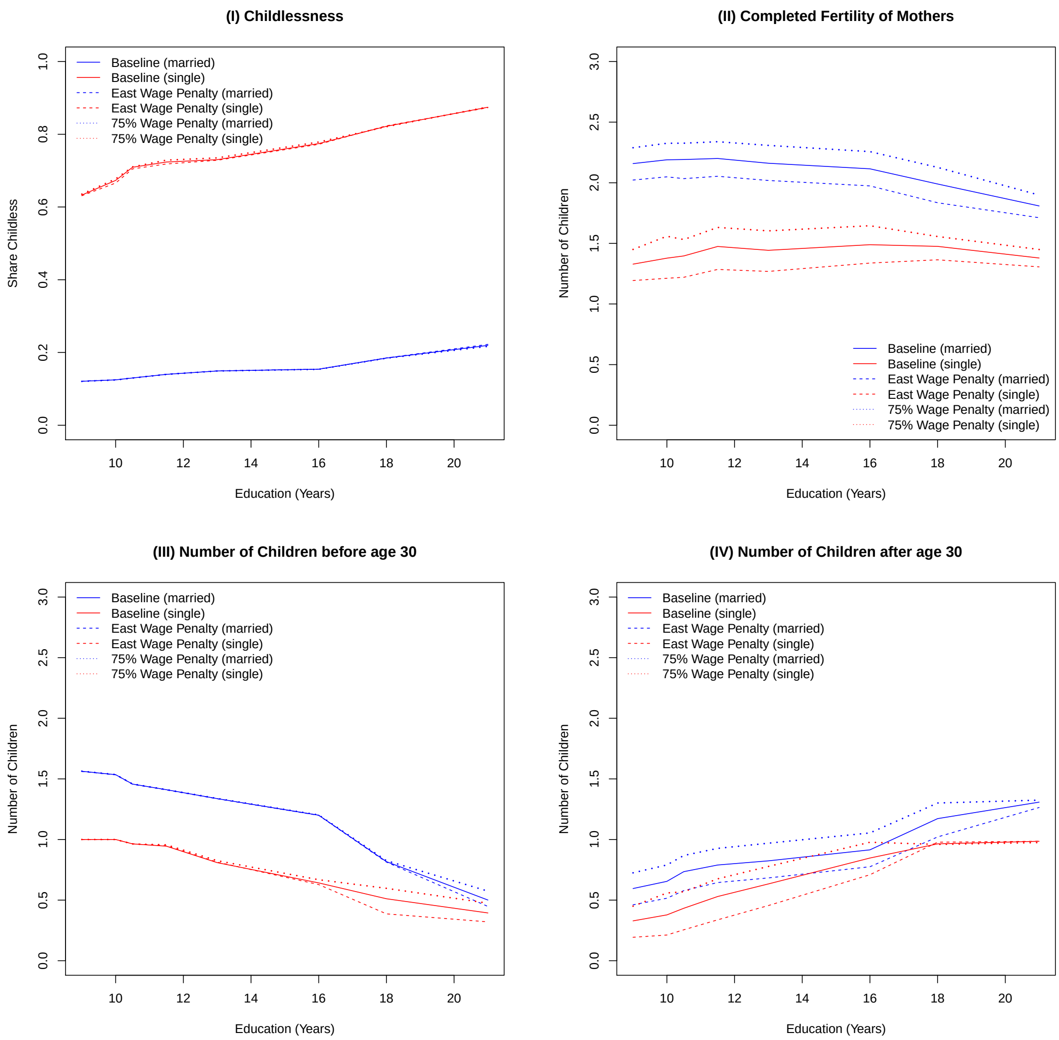
5.2 The Wage Effect of Spacing Children across Time

The other major difference between the East and West German sub-sample concerns the wage penalty for having children in both periods, which is the parameter of interest for this counterfactual experiment. The results of changes in the parameter ϵ to West Germany are illustrated in Figure 7 and Tables A.18 and A.19 in the Appendix. The comparison of the counterfactual experiments with the empirical moments is illustrated in Figure A.4 in the Appendix. The solid line plots the baseline moments. The dashed line plots the results for the application of the East German wage penalty (ϵ) to West Germany. The dotted line plots the result of a 25% reduction in the wage penalty (ϵ).

The wage penalty affects only individuals who choose to have children in both periods. Provided that there are no changes in the marital status, a decrease in the parameter should only

[51] Data taken from the Human Fertility Database (www.humanfertility.org)

Figure 7: Application of Alternative Wage Penalties to West Germany



Notes: Counterfactual Simulation - Simulating changes in the wage penalty (ϵ). Solid lines are the baseline results moments, dashed lines are simulation results for the application of the East German wage penalty (ϵ), dotted lines are the simulation results for a 25% decrease in the wage penalty (ϵ).

affect fertility rates, leaving the childlessness rates unaffected.[52] The reaction of the childlessness rate to a change in the labor market attachment risk are very small for both married and single women (see Tables A.20, A.21 and A.22). This indicates that the labor market attachment channel does not influence the marriage decision substantially. In addition, there are almost no changes in the reasons for childlessness as indicated by Table A.20 for the full childless population and Table A.21 and Table A.22 in the Appendix for the heterogeneity analysis with respect to marital status.

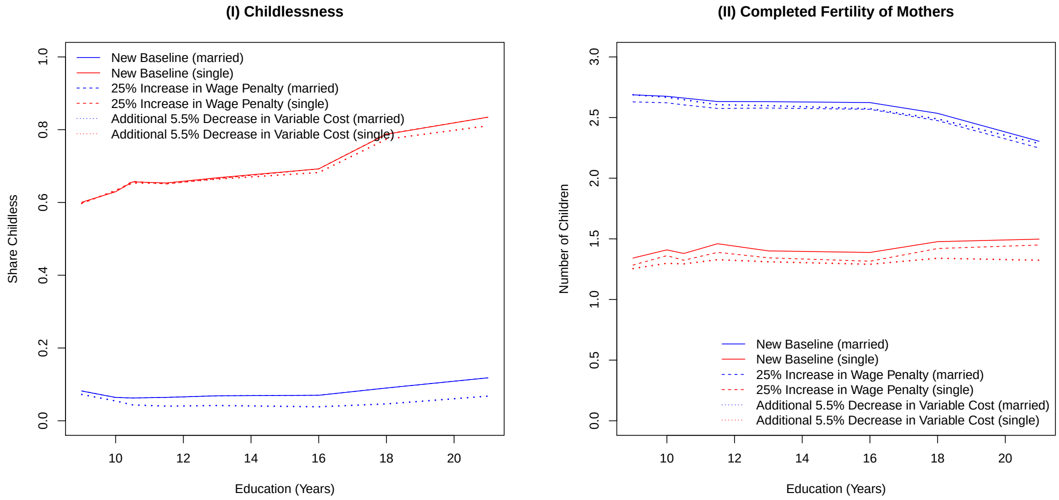
When applying the East German wage penalty to West Germany, I observe declining fertility rates for both married and single women across all education levels. The effect size is slightly smaller for highly educated women, as those are less likely to space children across time in baseline already. The opposite effect can be observed for the 25% decrease in the wage penalty. For most women the wage penalty of spacing children across affects only the number of children born after age 30. However, the opposite is true for highly educated women, who are more likely to postpone motherhood. As a result of lower costs of spacing children across time, all individuals are more likely to have an additional child in the period in which they would otherwise not have children.

5.3 Counteracting the Wage Penalty by Expansion of Public Childcare

In a last counterfactual experiment, I show how increases in the wage penalty of spacing children across time (ϵ) can be counteracted by reductions in the variable cost of children (ϕ). In particular, I assume a 25% increase in the wage penalty (ϵ) and a counteracting 5.5% decrease in the variable cost of children (ϕ). The increase in the wage penalty can come in many forms. Either through discrimination of women spending extended periods of time taking care of their children, or in the form of human capital depreciation. A possible example of human capital depreciation is automation and artificial intelligence, which fundamentally changes the way we work and has the potential to render some currently useful human capital obsolete in the future. Not keeping up with the quickly changing work environment and adopting important human capital can negatively affect future wages. The reduction in the variable cost of children can come in many forms that are individual specific, such as investments in the child's human capital in publicly available childcare. The new baseline scenario uses the baseline results for Germany.

[52] In the first period, sterility is the only driver of involuntary childlessness. If sterile, the woman (or couple) does not have children. If not sterile, the women (or couple) will not be childless.

Figure 8: Changes in Wage Penalty and Variable Costs of Children



Notes: Counterfactual Simulation - Simulation of a 25% increase in the wage penalty (ϵ) and a counteracting 5.5% reduction in the variable cost of children (ϕ). Regular lines indicates the new baseline simulation, dashed lines illustrate the application of only a 25% increase in the wage penalty (ϵ) and dotted lines indicate an additional 5.5% reduction in the variable cost of children (ϕ).

Furthermore, I apply the East German cost of children and the West German cost of spacing children across time for a more realistic baseline comparison for the future.

The results are illustrated in Figure 8. A figure including fertility per period (Figure A.5) and tables indicating the differences per education group (Table A.23 and Table A.24) are in the Appendix. The solid line plots the new baseline moments. The dashed line plots the results for the application of a 25% increase in the wage penalty (ϵ). The dotted line illustrates an additional counteracting 5.5% decrease in the variable cost of children (ϕ).

In line with the previous results of changes in the wage penalty, as documented in Section 5.2, the increase in the wage penalty has no influence on childlessness. For the number of children, conditional on being a mother, I observe a parallel downward shift of the completed fertility curve for both married and single women. When additionally applying a 5.5% reduction to the variable cost of children, heterogeneous effects by education and marital status can be observed along both margins of fertility. Childlessness decreases for all education levels, with larger effects for highly educated women, both single and married. The 5.5% reduction in the variable cost of children leads to an increase in completed fertility for married women across all education groups. The effect is largest for very low and very highly educated women. For those two groups, the decrease in variable cost of children almost completely offsets the reduction in completed fertility due to the increase in the wage penalty. For single women, we observe an additional decrease in completed fertility across all education groups. Similar to the observations from previous counterfactuals, this is the result of single women now transitioning out of childlessness to motherhood and from single-hood to marriage.

6 Conclusion

This paper presents a structural estimation of fertility and childlessness that includs various potential causes of the observed low fertility rates that Germany experienced since the early 1980s. The structural model parameters are identified using labor market conditions of individuals combined with distinct features of fertility behavior. The research provides novel insights into the interaction of economic and biologic channels in determining childlessness.

The model allows me to decompose the reasons for childlessness into voluntary and involuntary childlessness. Even though voluntary childlessness is the main driving factor for high rates of childlessness, I find that a substantial share of childlessness is involuntary. Women who choose to have children late in life and suffer from decreasing fecundity explain 7.6% of total childlessness. The effect size increases by education from 4.4% for women with only a low level of secondary education to 15.6% for women holding a PhD. I quantify the disutility of childlessness in terms of equivalent consumption and find larger effects for married women compared to single women and for sterility compared to infertility.

I perform a sample split between former East and West Germany to further investigate the impact of institutional differences between those two former states. When looking at the cost of the first child, I find consistently smaller costs of children in East Germany compared to West Germany across both periods. However, the gap between East and West Germany decreases substantially over time, which may be a result of the expansion of the provision of publicly available childcare and/or the availability of informal childcare in West Germany. The long lasting persistent differences between East and West Germany with respect to time cost of children result in higher levels of social sterility and involuntary childlessness due to postponement of having children in West Germany.

Lastly, I perform several counterfactual analyses. I show that lowering the costs of children can result in lower rates of childlessness and higher rates of fertility, conditional on having at least one child. However, the inter-temporal allocation of children is much more affected than the final number of children born to mothers. Nevertheless, expansion of public childcare would result in a lower age at first birth of women, a lower number of women who remain childless and a higher completed fertility, conditional on having children. I also show that increases in the negative wage effects of spacing children across time can be counteracted by reductions in the variable costs of children. Those reductions can come in any child-specific human capital investment, such as public provision of after school care that helps children develop their talents and prepare for school.

References

Adda, Jèrôme, Christian Dustmann, and Katrien Stevens (2017). "The Career Costs of Children." In: *Journal of Political Economy* 125.2, pp. 293 –328.

Baudin, Thomas, David De La Croix, and Paula E. Gobbi (2015). "Fertility and childlessness in the United States." In: *American Economic Review* 105.6, pp. 1852–1882.

Baudin, Thomas, David De La Croix, and Paula Eugenia Gobbi (2017). "Endogenous Childlessness and Stages of Development." In: *mimeo*, pp. 1–81.

Becker, Gary S. and Robert J. Barro (1988). "A Reformulation of the Economic Theory of Fertility." In: *The Quarterly Journal of Economics* 103.1, pp. 1–25.

Becker, Gary S, Kevin M Murphy, and Robert Tamura (1990). "Human Capital , Fertility , and Economic Growth." In: *Journal of Political Economy* 98.5 (Part 2), pp. 12–37.

Bertrand, Marianne, Claudia Goldin, and Lawrence F. Katz (2010). "Dynamics of the gender gap for young professionals in the financial and corporate sectors." In: *American Economic Journal: Applied Economics* 2.3, pp. 228–255. arXiv: arXiv:1011.1669v3.

Budig, Michelle J. and Paula England (2001). "The Wage Penalty for Motherhood." In: *American Sociological Review* 66.2, pp. 204–225. arXiv: arXiv:1011.1669v3.

Bumpass, Larry and Charles F. Westoff (1970). "Unwanted Births and U . S . Population Growth." In: *Family Planning Perspectives* 2.4, pp. 9–11.

Caucutt, E.M., N. Guner, and J. Knowles (2002). "Why do women wait? Matching, wage inequality and incentives for fertility delay." In: *Review of Economic Dynamics* 855, pp. 815–855.

Chevalier, Arnaud and Olivier Marie (2017). "Economic uncertainty, parental selection, and children's educational outcomes." In: *Journal of Political Economy* 125.2, pp. 393–430.

Chiappori, Pierre-Andre (1988). "Rational Household Labor Supply." In: *Econometrica* 56.1, pp. 63–90.

Chiappori, Pierre-Andre, Bernard Salanie, and Yoram Weiss (2017). "Partner choice, investment in children, and the marital college premium." In: *American Economic Review* 107.8, pp. 1–66.

Doepke, Matthias (2004). "Accounting for fertility decline during the transition to growth." In: *Journal of Economic Growth* 9.3, pp. 347–383.

Echevarria, Cristina and Antonio Merlo (1999). "Gender Differences in Education in a Dynamic Household Bargaining Model." In: *International Economic Review* 40.2, pp. 265–286.

Galor, Oded (2011). *Unified Growth Theory.* Princeton, N.J.: Princeton University Press.

Galor, Oded and David N. Weil (2000). "Population, Technology, and Growth: From Malthusian Stagnation to the Demographic Transition and Beyond." In: *American Economic Review* 90.4, pp. 807–828.

García-Morán, Eva and Zoë Kuehn (2017). "With strings attached: Grandparent-provided child care and female labor market outcomes." In: *Review of Economic Dynamics* 23, pp. 80–98.

Greenwood, J., N. Guner, and J.A. Knowles (2003). "More on Marriage, Fertility, and the Distribution of Income." In: *International Economic Review* 44.3, pp. 827–862.

Greenwood, Jeremy and Nezih Guner (2009). "Marriage and Divorce Since World War II: Analyzing the Role of Technological Progress on the Formation of Households." In: *NBER Macroeconomics Annual 2008* 23.23, pp. 231–276.

Herr, Jane Leber (2016). "Measuring the effect of the timing of first birth on wages." In: *Journal of Population Economics* 29.1, pp. 39–72.

Iyigun, Murat and Randall P. Walsh (2007). "Endogenous gender power, household labor supply and the demographic transition." In: *Journal of Development Economics* 82.1, pp. 138–155.

Jones, Larry E., Alice Schoonbroodt, and Michèle Tertilt (2010). *Fertility Theories: Can They Explain the Negative Fertility-Income Relationship?* Ed. by John B. Shoven. Chicago: University of Chicago Press, pp. 43–100.

Knodel, A. J. (1974). *The Decline of Fertility in Germany, 1871-1939.* Princeton, N.J.: Princeton University Press.

Lafortune, Jeanne and Corinne Low (2017). "Tying the double-knot: The role of assets in marriage commitment." In: *American Economic Review: Papers & Proceedings* 107.5, pp. 163–167.

Lee, Ronald (2003). "The demographic transition: Three centuries of fundamental change." In: *Journal of Economic Perspectives* 17.4, pp. 167–190.

Leridon, Henri (2004). "Can assisted reproduction technology compensate for the natural decline in fertility with age? A model assessment." In: *Human Reproduction* 19.7, pp. 1548–1553.

Low, Corinne (2017). "A "Reproductive Capital" Model of Marriage Market Matching." In: *mimeo*, pp. 1–82.

Lundborg, Petter, Erik Plug, and Astrid Würtz Rasmussen (2017). "Can Women Have Children and a Career? IV Evidence from IVF Treatments." In: *American Economic Review* 107.6, pp. 1611–1637.

Miller, Amalia R. (2011). "The effects of motherhood timing on career path." In: *Journal of Population Economics* 24.3, pp. 1071–1100.

Mosher, William D, Jo Jones, and Joyce C Abma (2012). "Intended and unintended births in the United States: 1982-2010." In: *National health statistics reports* 55, pp. 1–28.

Myong, Sunha, JungJae Park, and Junjian Yi (2018). "Social Norms and Fertility."

Pollak, R. a. (2005). "Bargaining Power in Marriage: Earnings, Wage Rates and Household Production." In: *NBER working paper series* 11239, pp. 1–29.

Powell, M. J D (2002). "UOBYQA: Unconstrained optimization by quadratic approximation." In: *Mathematical Programming, Series B* 92.3, pp. 555–582.

Regalia, Ferdinando, Jose-Victor Rios-Rull, and Jacob Short (2011). "What Accounts for the Increase in Single Households ?" In: *mimeo*, pp. 0–44.

Rios-Rull, Jose-Victor (1993). "Working in the Market , Working at Home , and the Acquisition of Skills : A General- Equilibrium Approach." In: *American Economic Review* 83.4, pp. 893–907.

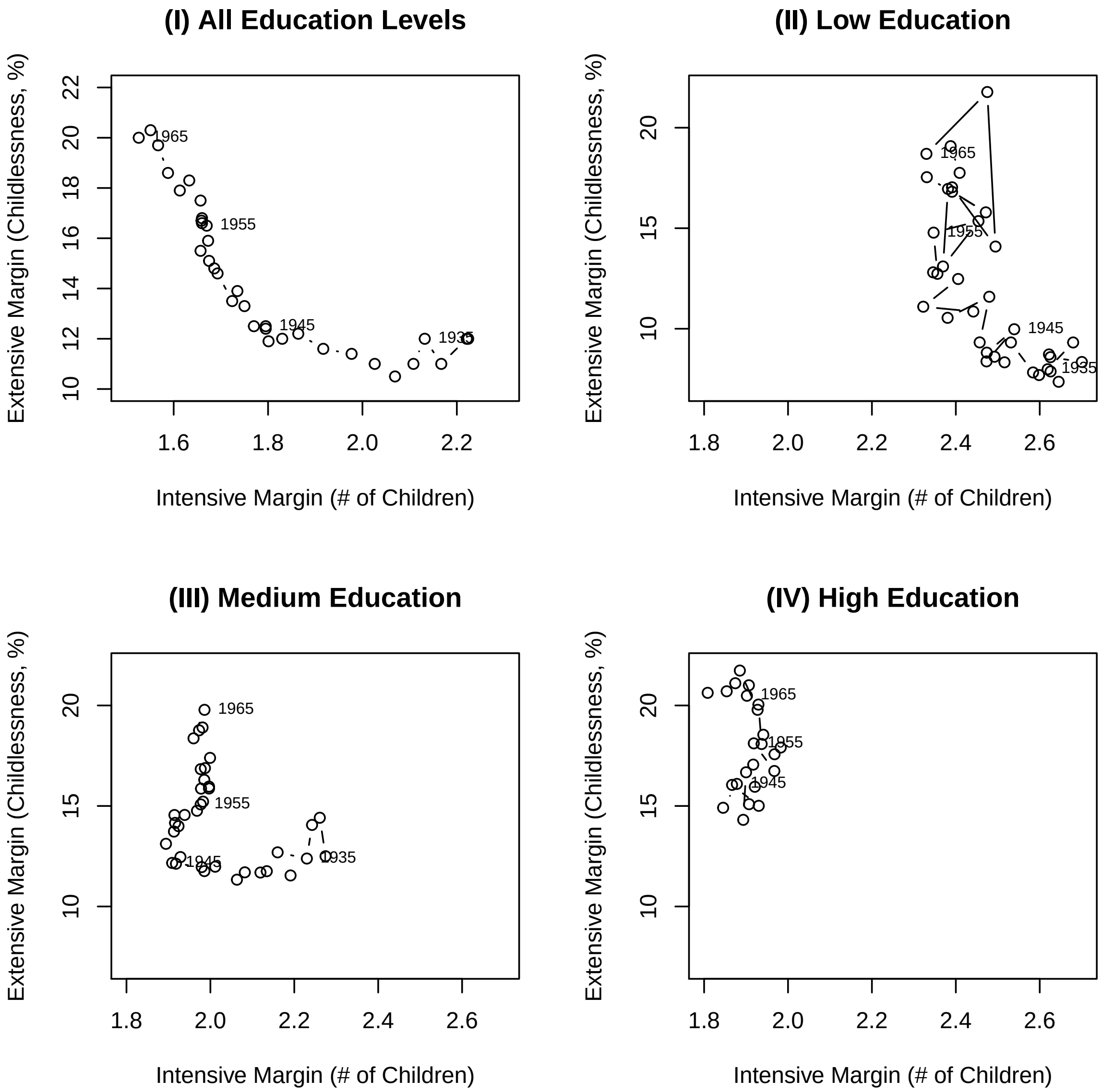
Tietze, Christopher (1957). "Reproductive span and rate of reproduction among hutterite women." In: *Fertility and Sterility* 8.1, pp. 89–97.

Wood, Robert G., Mary E. Corcoran, and Paul N. Courant (1993). "Pay Differences among the Highly Paid: The Male-Female Earnings Gap in Lawyers' Salaries." In: *Journal of Labor Economics* 11.3, pp. 417–441.

A Appendix

A.1 Historic Development by Mother's Education

Figure A.1: Fertility along the intensive and extensive Margin - by Education



Notes: Childlessness (y-axis) is defined as the share of the female population that remains without children by age 45. Average Completed Fertility (x-axis) is the total fertility of all women above age 45. Women with a low education level (≤ 9 years of schooling) are plotted black, women with some sort of vocational training (years of schooling > 9 & < 13) are plotted blue and women with a high level of education (years of schooling ≥ 13) are plotted red. Due to the low number of women with a high level of education in the birth cohorts before 1945, those cohorts are not plotted for the high education subgroup. *Data*: German Microcensus, survey years 2008 & 2012, own calculations.

A.2 Cross Country Comparison for TFR and Childlessness

Table A.1: TFR and Childlessness: Cross Country Comparison

Country	TFR	Childlessness	Data Source
Austria	1.52	0.21	OECD Family Database
Czech Republic	1.69	0.08	
Denmark	1.75	0.13	
Estonia	1.59	0.10	
Finland	1.49	0.21	
Hungary	1.49	0.12	
Japan	1.43	0.27	
Lithuania	1.63	0.12	
Netherlands	1.62	0.18	
Norway	1.62	0.11	
Poland	1.45	0.16	
Portugal	1.37	0.07	
Slovak Republic	1.52	0.12	
Slovenia	1.62	0.12	
Spain	1.31	0.18	
Sweden	1.78	0.12	
United States	1.77	0.12	
Argentina	2.26	0.30	Myong, Park and Yi (2018)
Cameroon	4.64	0.18	
China	1.60	0.08	
Hong Kong	1.19	0.12	
Singapore	0.83	0.24	
Tanzania	4.77	0.09	
Uruguay	1.08	0.27	

Note: For countries where data is obtained from the OECD Family Database, TFR are measured in 2017, whereas childlessness is measured for women born in 1970. For countries where data is obtained from Myong, Park and Yi (2018), childlessness is calculated by multiplying marriage rates with childlessness rates conditional on marital status.

A.3 Wage Regressions

Table A.2: Years of Education by Educational Type

Education Type	Education Title	Years
Secondary Education	Hauptschule	9.0
	Polytech. Oberschule DDR	10.0
	Realschule	10.0
	Fachhochschulereife	12.0
	Abitur	13.0
Tertiary Education	Anlernung	0.0
	Berufsvorbereitungsjahr	1.0
	Lehre	1.5
	Berufsschule	1.5
	Beamtenschule	1.5
	Gesundheit (1 Jahr)	2.0
	Meister	2.5
	Fachschule DDR	2.0
	Fachakademie (Bayern)	2.0
	FH	3.0
	Uni	5.0
	PhD	8.0

Note: Assignment of years of education to educational degrees following the procedure used in the GSOEP.

Table A.3: Descriptive Statistics (GSOEP)

Statistic	N	Mean	St. Dev.
Education (Years)	50,520	12.35	2.63
Experience (Years)	50,520	15.20	7.82
Gross Labor Income (EUR)	50,520	2,317.01	1,540.43
Net Labor Income (EUR)	50,520	1,514.72	963.03
Net Wage (EUR)	50,520	16.42	11.81
Log Wage	50,520	2.66	0.52

Table A.4: Regression Output

	Dependent variable:
	Net Labor Income (log)
Male	0.232***
	(0.002)
Education	−0.075***
	(0.011)
Education(sq)	0.008***
	(0.001)
Education(cu)	−0.0001***
	(0.00002)
Experience	0.039***
	(0.001)
Experience(sq)	−0.001***
	(0.00003)
Experience(cu)	0.00001***
	(0.00000)
Constant	1.991***
	(0.045)
Observations	225,805
R^2	0.332
Adjusted R^2	0.332
Residual Std. Error	0.348 (df = 225797)
F Statistic	16,065.220*** (df = 7; 225797)
Note:	*p<0.1; **p<0.05; ***p<0.01

A.4 Model Fit: Normalized Differences

Table A.5: Model Fit: Childlessness

Marital Status	Education (Group)	Model	Data	Std. Dev.	Norm. Diff.
Single Women	1	0.619	0.662	0.473	0.091
	2	0.644	0.709	0.454	0.144
	3	0.681	0.718	0.450	0.083
	4	0.673	0.710	0.454	0.081
	5	0.688	0.675	0.468	0.029
	6	0.734	0.711	0.453	0.052
	7	0.809	0.770	0.421	0.093
	8	0.846	0.812	0.391	0.087
Married Women	1	0.094	0.070	0.255	0.094
	2	0.080	0.103	0.304	0.075
	3	0.084	0.095	0.294	0.037
	4	0.089	0.104	0.305	0.048
	5	0.102	0.098	0.297	0.013
	6	0.108	0.113	0.316	0.016
	7	0.137	0.146	0.353	0.027
	8	0.176	0.160	0.367	0.042

Table A.6: Model Fit: Children before Age 30

Marital Status	Education (Group)	Model	Data	Std. Dev.	Norm. Diff.
Single Women	1	1.000	1.160	0.924	0.173
	2	1.000	0.996	0.794	0.005
	3	1.000	1.145	0.946	0.153
	4	0.997	0.968	0.885	0.032
	5	0.889	0.938	0.833	0.059
	6	0.745	0.766	0.703	0.029
	7	0.517	0.527	0.735	0.013
	8	0.400	0.407	0.591	0.011
Married Women	1	1.625	1.836	1.081	0.195
	2	1.597	1.719	1.093	0.113
	3	1.584	1.514	0.913	0.076
	4	1.511	1.437	0.954	0.078
	5	1.444	1.322	0.964	0.127
	6	1.370	1.098	0.958	0.284
	7	0.989	0.840	0.922	0.161
	8	0.575	0.632	0.943	0.061

Table A.7: Model Fit: Children after Age 30

Marital Status	Education (Group)	Model	Data	Std. Dev.	Norm. Diff.
Single Women	1	0.273	0.398	0.642	0.194
	2	0.354	0.366	0.612	0.019
	3	0.348	0.447	0.590	0.168
	4	0.406	0.512	0.688	0.153
	5	0.500	0.486	0.686	0.021
	6	0.667	0.643	0.678	0.034
	7	0.970	0.871	0.697	0.142
	8	0.973	1.149	0.864	0.204
Married Women	1	0.607	0.488	0.761	0.157
	2	0.644	0.528	0.820	0.141
	3	0.669	0.505	0.734	0.225
	4	0.718	0.569	0.776	0.191
	5	0.809	0.651	0.834	0.189
	6	0.850	0.822	0.879	0.032
	7	1.106	1.116	0.945	0.011
	8	1.327	1.400	0.943	0.078

Table A.8: Model Fit: Marriage Rates

Gender	Education (Group)	Model	Data	Std. Dev.	Norm. Diff.
Women	1	0.920	0.956	0.319	0.111
	2	0.915	0.926	0.390	0.027
	3	0.914	0.951	0.349	0.105
	4	0.912	0.922	0.406	0.025
	5	0.905	0.898	0.428	0.016
	6	0.899	0.874	0.442	0.058
	7	0.876	0.860	0.443	0.038
	8	0.857	0.813	0.457	0.097
Men	1	0.922	0.860	0.418	0.148
	2	0.918	0.836	0.449	0.183
	3	0.908	0.908	0.383	0.002
	4	0.914	0.898	0.403	0.039
	5	0.900	0.865	0.429	0.082
	6	0.900	0.907	0.382	0.018
	7	0.877	0.883	0.396	0.014
	8	0.860	0.914	0.357	0.151

A.5 Additional Baseline Results

Table A.9: Reasons for Childlessness (Baseline)

	All Childless Women						Single Childless Women						Married Childless Women					
			Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness	
Education	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement
1	0.786	0.214	0.457	0.543	0.793	0.207	0.996	0.004	0.990	0.010	1.000	0.000	0.208	0.792	0.000	1.000	1.000	0.000
2	0.781	0.219	0.531	0.469	0.746	0.254	0.996	0.004	0.974	0.026	1.000	0.000	0.255	0.745	0.000	1.000	1.000	0.000
3	0.784	0.216	0.518	0.482	0.724	0.276	0.990	0.010	0.955	0.045	1.000	0.000	0.282	0.718	0.000	1.000	1.000	0.000
4	0.762	0.238	0.522	0.478	0.615	0.385	0.993	0.007	0.947	0.053	0.750	0.250	0.387	0.613	0.000	1.000	1.000	0.000
5	0.741	0.259	0.528	0.472	0.557	0.443	0.989	0.011	0.954	0.046	0.714	0.286	0.445	0.555	0.000	1.000	1.000	0.000
6	0.776	0.224	0.488	0.512	0.535	0.465	0.986	0.014	0.887	0.113	0.300	0.700	0.458	0.542	0.000	1.000	1.000	0.000
7	0.773	0.227	0.481	0.519	0.359	0.641	0.983	0.017	0.833	0.167	0.176	0.824	0.635	0.365	0.000	1.000	1.000	0.000
8	0.771	0.229	0.382	0.618	0.318	0.682	0.987	0.013	0.672	0.328	0.188	0.812	0.679	0.321	0.000	1.000	1.000	0.000

Note: Reasons for childlessness by women's education. Sample restricted to women/couples who are childless in baseline. Left block contains all women, the middle block all single women and the right block all married women, who are childless. Values within one line per sub-block add up to one. The blocks "Voluntary Childlessness" and "Involuntary Childlessness" contain the sub-groups of "Voluntary" and "Involuntary", respectively. Values rounded.

Table A.10: Timing of Involuntary Childlessness (Baseline)

	Married Childless Women		Single Childless Women		Married Childless Men	
Education	Period 1	Period 2	Period 1	Period 2	Period 1	Period 2
1	0.717	0.283	1.000	0.000	0.656	0.344
2	0.664	0.336	1.000	0.000	0.617	0.383
3	0.631	0.369	1.000	0.000	0.583	0.417
4	0.507	0.493	0.750	0.250	0.479	0.521
5	0.425	0.575	0.714	0.286	0.422	0.578
6	0.352	0.648	0.300	0.700	0.353	0.647
7	0.192	0.808	0.059	0.941	0.211	0.789
8	0.079	0.921	0.062	0.938	0.116	0.884

Note: Reasons for involuntary childlessness. Sample restricted to women/couples who are involuntariy childless. Period refers to the period in which sterility/infertility is realized by individuals. Values rounded.

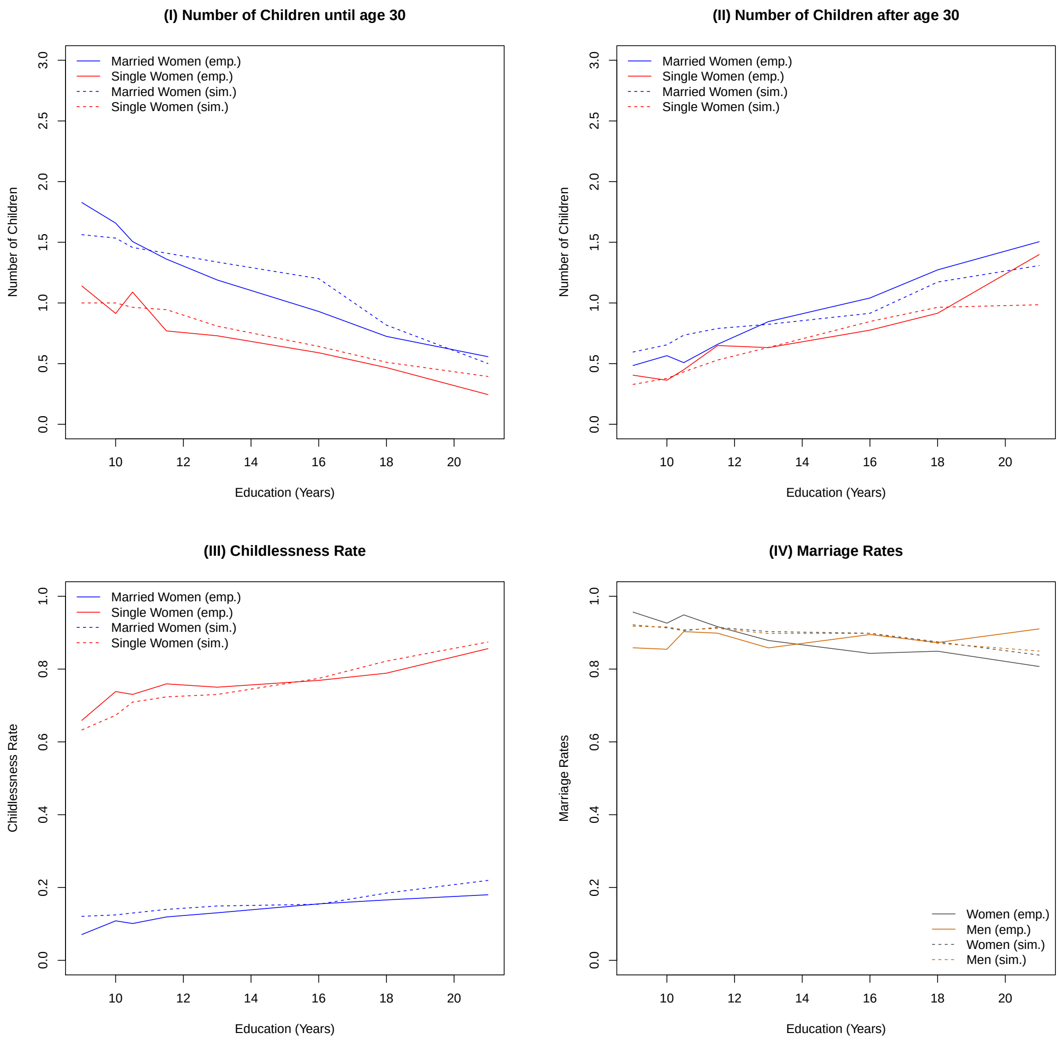
A.6 Additional Sub-sample Results

Table A.11: Estimation Results for Subsamples

Parameter	Description	Baseline	West	East	2008	2012
β	Discount factor	0.971	0.954	0.964	0.971	0.994
		(0.008)	(0.011)	(0.005)	(0.009)	(0.009)
σ_a	Standard deviation of the log-normal distribution	0.513	0.537	0.500	0.513	0.524
		(0.003)	(0.003)	(0.005)	(0.004)	(0.003)
ν	Preference parameter	6.137	6.010	6.129	6.237	6.154
		(0.013)	(0.011)	(0.011)	(0.011)	(0.012)
μ	Good cost to be supported by a household	0.677	0.689	0.658	0.677	0.678
		(0.005)	(0.005)	(0.010)	(0.005)	(0.006)
α	Fraction of child-rearing to be supported by women	0.546	0.554	0.537	0.546	0.535
		(0.003)	(0.004)	(0.005)	(0.004)	(0.008)
ϕ	Time cost of having children	0.620	0.617	0.600	0.620	0.623
		(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
η_1	Fixed cost of children (period 1)	0.187	0.198	0.074	0.187	0.192
		(0.003)	(0.003)	(0.004)	(0.003)	(0.003)
δ_m	Time cost for being single (men)	0.321	0.346	0.345	0.321	0.331
		(0.010)	(0.010)	(0.010)	(0.010)	(0.011)
δ_f	Time cost for being single (women)	0.106	0.105	0.157	0.106	0.103
		(0.003)	(0.010)	(0.006)	(0.004)	(0.003)
$\hat{c}$	Minimum consumption level for procreation	0.461	0.417	0.445	0.461	0.462
		(0.003)	(0.003)	(0.007)	(0.003)	(0.003)
$\overline{m}_a$	Average ratio of non-labor income to labor income	1.327	1.211	1.344	1.327	1.314
		(0.005)	(0.005)	(0.009)	(0.005)	(0.006)
ϵ	Wage effect of spacing children across time	0.617	0.544	0.719	0.617	0.614
		(0.008)	(0.008)	(0.012)	(0.008)	(0.007)
η_2	Fixed cost of children (period 2)	0.013	0.005	0.041	0.013	0.010
		(0.003)	(0.003)	(0.004)	(0.003)	(0.003)
ω	Share of randomly matched on marriage market	0.427	0.498	0.452	0.427	0.428
		(0.011)	(0.011)	(0.010)	(0.012)	(0.011)

Note: Estimated parameters of the model for different data subsets (West Germany, East Germany, 2008 Microcensus and 2012 Microcensus). Parameters for wages and natural sterility and infertility are set. For readability bootstrapped standard errors are reported in brackets.

Figure A.2: Model Fit for West Germany



Notes: Internal fit of the simulated model for West Germany only. Lines are empirical moments, dashed lines are simulation results. (I) Completed Fertility for married (blue) and single (red) women for different educational groups. (II) Childlessness rate for married (blue) and single (red) women for different education groups. (III) Fertility of mothers until age 30 for married (blue) and single (red) women for different education groups. (IV) Fertility of mothers after age 30 for married (blue) and single (red) women for different education groups. (V) Marriage rates for women (gray) and men (orange) for different education groups. (VI) Divorce rates for women (gray) and men (orange) for different education groups. *Data*: German Microcensus, survey years 2008 & 2012, own calculations.

Table A.12: Reasons for Childlessness (West Germany, Sub-Samples)

	All Childless Women						Single Childless Women						Married Childless Women					
			Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness	
Education	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement
1	0.819	0.181	0.371	0.629	0.704	0.296	0.996	0.004	0.988	0.012	1.000	0.000	0.740	0.260	0.000	1.000	0.702	0.298
2	0.831	0.169	0.397	0.603	0.656	0.344	0.993	0.007	0.981	0.019	1.000	0.000	0.748	0.252	0.000	1.000	0.652	0.348
3	0.819	0.181	0.432	0.568	0.579	0.421	0.991	0.009	0.982	0.018	0.833	0.167	0.720	0.280	0.000	1.000	0.574	0.426
4	0.786	0.214	0.395	0.605	0.505	0.495	0.994	0.006	0.959	0.041	1.000	0.000	0.686	0.314	0.000	1.000	0.500	0.500
5	0.795	0.205	0.410	0.590	0.504	0.496	0.990	0.010	0.956	0.044	0.714	0.286	0.693	0.307	0.000	1.000	0.500	0.500
6	0.787	0.213	0.419	0.581	0.463	0.537	0.983	0.017	0.925	0.075	0.231	0.769	0.676	0.324	0.000	1.000	0.470	0.530
7	0.799	0.201	0.406	0.594	0.333	0.667	0.987	0.013	0.844	0.156	0.154	0.846	0.679	0.321	0.000	1.000	0.337	0.663
8	0.812	0.188	0.368	0.632	0.300	0.700	0.992	0.008	0.694	0.306	0.273	0.727	0.674	0.326	0.000	1.000	0.300	0.700

Note: Reasons for childlessness by women's education. Sample restricted to women/couples who are childless in West Germany. Left block contains all women, the middle block all single women and the right block all married women, who are childless. Values within one line per sub-block add up to one. The blocks "Voluntary Childlessness" and "Involuntary Childlessness" contain the sub-groups of "Voluntary" and "Involuntary", respectively. Values rounded.

Table A.13: Reasons for Childlessness (East Germany, Sub-Samples)

	All Childless Women						Single Childless Women						Married Childless Women					
			Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness	
Education	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement
1	0.756	0.244	0.374	0.626	0.933	0.067	0.987	0.013	0.980	0.020	1.000	0.000	0.661	0.339	0.000	1.000	0.931	0.069
2	0.788	0.212	0.332	0.668	0.896	0.104	0.993	0.007	0.975	0.025	1.000	0.000	0.712	0.288	0.000	1.000	0.895	0.105
3	0.789	0.211	0.372	0.628	0.892	0.108	0.991	0.009	0.980	0.020	1.000	0.000	0.702	0.298	0.000	1.000	0.890	0.110
4	0.767	0.233	0.376	0.624	0.876	0.124	0.991	0.009	0.976	0.024	1.000	0.000	0.672	0.328	0.000	1.000	0.875	0.125
5	0.802	0.198	0.384	0.616	0.894	0.106	0.987	0.013	0.981	0.019	1.000	0.000	0.716	0.284	0.000	1.000	0.891	0.109
6	0.807	0.193	0.364	0.636	0.894	0.106	0.995	0.005	0.953	0.047	1.000	0.000	0.723	0.277	0.000	1.000	0.893	0.107
7	0.816	0.184	0.366	0.634	0.675	0.325	0.998	0.002	0.906	0.094	1.000	0.000	0.726	0.274	0.000	1.000	0.674	0.326
8	0.807	0.193	0.307	0.693	0.446	0.554	0.991	0.009	0.743	0.257	0.571	0.429	0.714	0.286	0.000	1.000	0.444	0.556

Note: Reasons for childlessness by women's education. Sample restricted to women/couples who are childless in East Germany. Left block contains all women, the middle block all single women and the right block all married women, who are childless. Values within one line per sub-block add up to one. The blocks "Voluntary Childlessness" and "Involuntary Childlessness" contain the sub-groups of "Voluntary" and "Involuntary", respectively. Values rounded.

A.7 Counterfactual Tables

Table A.14: Effect of the East German Fixed Cost of Children for West Germany (η_1)

		1	2	3	4	5	6	7	8
Childlessness (married)	Value	0.116	0.118	0.120	0.123	0.132	0.136	0.169	0.208
	vs. Empirical	0.045	0.010	0.019	0.004	0.002	-0.019	0.003	0.028
	vs. Baseline	-0.005	-0.006	-0.010	-0.017	-0.017	-0.018	-0.016	-0.012
Childlessness (single)	Value	0.610	0.650	0.684	0.688	0.705	0.750	0.805	0.874
	vs. Empirical	-0.049	-0.088	-0.046	-0.071	-0.045	-0.019	0.016	0.018
	vs. Baseline	-0.023	-0.023	-0.025	-0.035	-0.025	-0.025	-0.017	-0.000
Fertility (married)	Value	2.196	2.215	2.206	2.197	2.172	2.164	2.049	1.876
	vs. Empirical	-0.116	-0.009	0.192	0.176	0.137	0.193	0.052	-0.186
	vs. Baseline	0.037	0.025	0.015	-0.004	0.011	0.049	0.059	0.067
Fertility (single)	Value	1.304	1.346	1.338	1.381	1.357	1.380	1.448	1.520
	vs. Empirical	-0.241	0.069	-0.202	-0.038	-0.004	0.014	0.066	-0.123
	vs. Baseline	-0.025	-0.033	-0.059	-0.093	-0.086	-0.109	-0.027	0.141

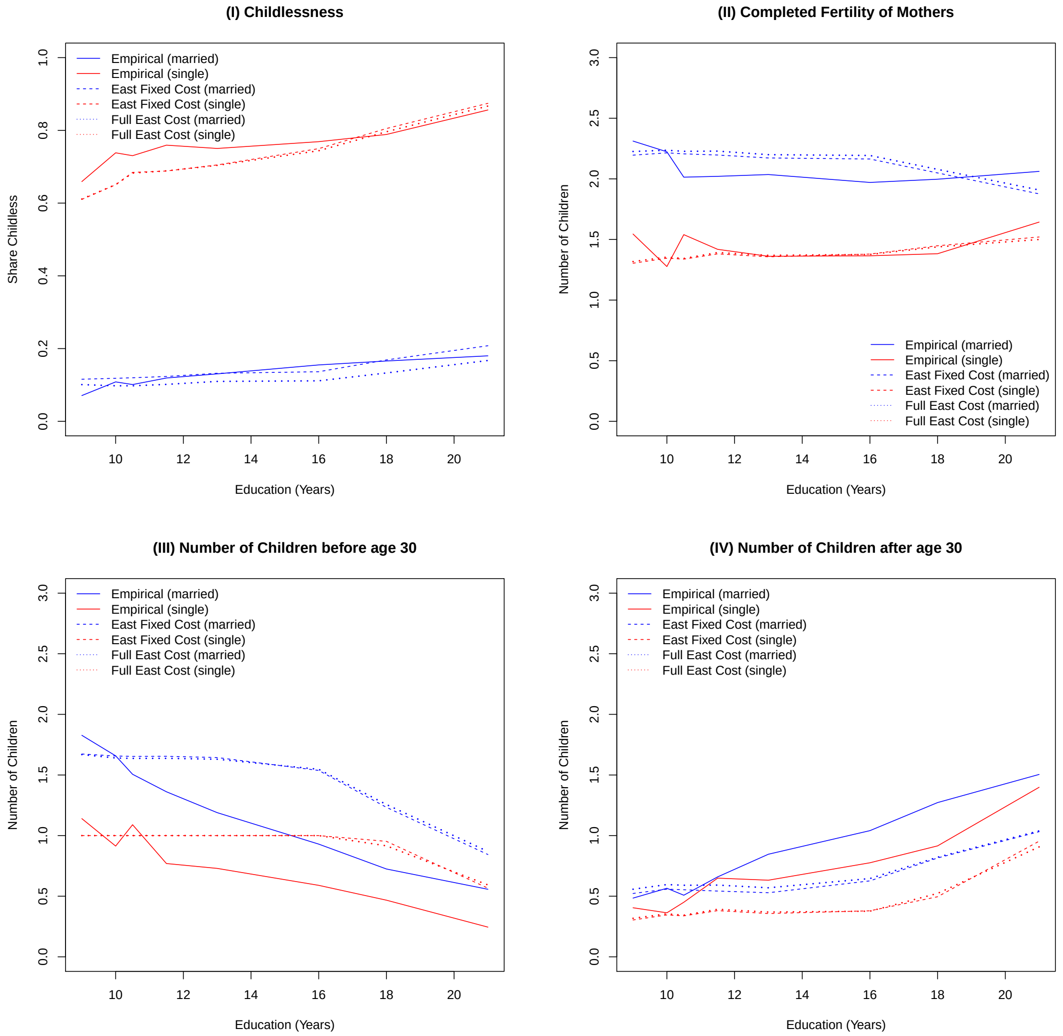
Note: Application of the East German fixed cost of becoming a mother in period 1 (η_1) to West Germany. VS.-rows are calculated by subtracting empirical values / baseline simulation results from the counterfactual results. Values rounded.

Table A.15: Effect of the East German Cost of Children for West Germany (η_1 & ϕ)

		1	2	3	4	5	6	7	8
Childlessness (married)	Value	0.091	0.079	0.083	0.085	0.094	0.098	0.123	0.171
	vs. Empirical	0.020	-0.030	-0.018	-0.034	-0.037	-0.057	-0.043	-0.010
	vs. Baseline	-0.030	-0.046	-0.047	-0.055	-0.055	-0.056	-0.062	-0.049
Childlessness (single)	Value	0.585	0.619	0.646	0.637	0.652	0.681	0.778	0.845
	vs. Empirical	-0.074	-0.119	-0.084	-0.123	-0.099	-0.088	-0.011	-0.011
	vs. Baseline	-0.048	-0.054	-0.063	-0.087	-0.079	-0.094	-0.044	-0.030
Fertility (married)	Value	2.294	2.295	2.296	2.263	2.281	2.279	2.199	1.997
	vs. Empirical	-0.017	0.072	0.282	0.242	0.245	0.309	0.202	-0.065
	vs. Baseline	0.136	0.106	0.105	0.062	0.120	0.164	0.209	0.188
Fertility (single)	Value	1.248	1.299	1.296	1.316	1.303	1.296	1.365	1.429
	vs. Empirical	-0.297	0.023	-0.244	-0.103	-0.058	-0.069	-0.017	-0.215
	vs. Baseline	-0.081	-0.079	-0.100	-0.158	-0.139	-0.193	-0.110	0.049

Note: Application of the East German cost of becoming a mother in period 1 (η) and the variable cost of children (ϕ) to West Germany. VS.-rows are calculated by subtracting empirical values / baseline simulation results from the counterfactual results. Values rounded.

Figure A.3: Application of the East German Children Production Costs (vs. Empirical Moments)



Notes: Counterfactual Simulation - Simulating the application of the East German children production costs to West Germany. Lines are empirical moments, dashed lines are simulation results for the application of the fixed cost (η_1) in period 1 only, dotted lines are the simulation results for the full application of the East German children production costs (η_1 & ϕ). *Data*: German Microcensus, survey years 2008 & 2012, own calculations.

Table A.16: Reasons for Childlessness (East German η_1 for West Germany , Sub-Samples)

	All Childless Women						Single Childless Women						Married Childless Women					
			Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness	
Education	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement
1	0.842	0.158	0.364	0.636	0.837	0.163	0.996	0.004	0.992	0.008	1.000	0.000	0.772	0.228	0.000	1.000	0.835	0.165
2	0.858	0.142	0.391	0.609	0.820	0.180	0.993	0.007	0.989	0.011	1.000	0.000	0.788	0.212	0.000	1.000	0.817	0.183
3	0.858	0.142	0.426	0.574	0.800	0.200	0.989	0.011	0.995	0.005	1.000	0.000	0.781	0.219	0.000	1.000	0.794	0.206
4	0.851	0.149	0.393	0.607	0.805	0.195	0.991	0.009	0.986	0.014	1.000	0.000	0.777	0.223	0.000	1.000	0.801	0.199
5	0.856	0.144	0.408	0.592	0.810	0.190	0.993	0.007	0.982	0.018	1.000	0.000	0.780	0.220	0.000	1.000	0.806	0.194
6	0.848	0.152	0.419	0.581	0.718	0.282	0.996	0.004	0.955	0.045	1.000	0.000	0.760	0.240	0.000	1.000	0.715	0.285
7	0.839	0.161	0.408	0.592	0.449	0.551	0.997	0.003	0.876	0.124	0.667	0.333	0.737	0.263	0.000	1.000	0.448	0.552
8	0.833	0.167	0.369	0.631	0.351	0.649	0.994	0.006	0.706	0.294	0.375	0.625	0.707	0.293	0.000	1.000	0.350	0.650

Note: Reasons for childlessness by women's education. Sample restricted to women/couples who are childless in the counterfactual for the application of the East German η_1 to West Germany. Left block contains all women, the middle block all single women and the right block all married women, who are childless. Values within one line per sub-block add up to one. The blocks "Voluntary Childlessness" and "Involuntary Childlessness" contain the sub-groups of "Voluntary" and "Involuntary", respectively. Values rounded.

Table A.17: Reasons for Childlessness (East German η_1 & ϕ for West Germany , Sub-Samples)

	All Childless Women						Single Childless Women						Married Childless Women					
			Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness	
Education	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement
1	0.813	0.187	0.407	0.593	0.809	0.191	0.996	0.004	0.991	0.009	1.000	0.000	0.721	0.279	0.000	1.000	0.808	0.192
2	0.832	0.168	0.451	0.549	0.790	0.210	0.993	0.007	0.989	0.011	1.000	0.000	0.733	0.267	0.000	1.000	0.787	0.213
3	0.839	0.161	0.489	0.511	0.807	0.193	0.991	0.009	0.995	0.005	1.000	0.000	0.731	0.269	0.000	1.000	0.803	0.197
4	0.821	0.179	0.454	0.546	0.784	0.216	0.991	0.009	0.986	0.014	1.000	0.000	0.716	0.284	0.000	1.000	0.780	0.220
5	0.827	0.173	0.474	0.526	0.763	0.237	0.992	0.008	0.988	0.012	1.000	0.000	0.716	0.284	0.000	1.000	0.759	0.241
6	0.823	0.177	0.486	0.514	0.708	0.292	0.996	0.004	0.965	0.035	1.000	0.000	0.700	0.300	0.000	1.000	0.705	0.295
7	0.813	0.187	0.485	0.515	0.476	0.524	0.997	0.003	0.898	0.102	0.667	0.333	0.668	0.332	0.000	1.000	0.474	0.526
8	0.800	0.200	0.432	0.568	0.347	0.653	0.993	0.007	0.719	0.281	0.333	0.667	0.619	0.381	0.000	1.000	0.347	0.653

Note: Reasons for childlessness by women's education. Sample restricted to women/couples who are childless in the counterfactual for the application of the East German η_1 and ϕ to West Germany. Left block contains all women, the middle block all single women and the right block all married women, who are childless. Values within one line per sub-block add up to one. The blocks "Voluntary Childlessness" and "Involuntary Childlessness" contain the sub-groups of "Voluntary" and "Involuntary", respectively. Values rounded.

Table A.18: Effect of the East German Wage Penalty for West Germany (ϵ)

		1	2	3	4	5	6	7	8
Childlessness (married)	Value	0.121	0.125	0.130	0.140	0.149	0.154	0.185	0.222
	vs. Empirical	0.050	0.017	0.029	0.021	0.019	-0.001	0.019	0.042
	vs. Baseline	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003
Childlessness (single)	Value	0.631	0.666	0.705	0.718	0.728	0.772	0.823	0.873
	vs. Empirical	-0.028	-0.072	-0.026	-0.041	-0.022	0.003	0.035	0.017
	vs. Baseline	-0.002	-0.007	-0.004	-0.005	-0.002	-0.002	0.001	-0.001
Fertility (married)	Value	2.022	2.049	2.034	2.054	2.019	1.974	1.835	1.712
	vs. Empirical	-0.289	-0.174	0.020	0.033	-0.017	0.004	-0.162	-0.350
	vs. Baseline	-0.136	-0.140	-0.158	-0.147	-0.142	-0.141	-0.155	-0.097
Fertility (single)	Value	1.193	1.212	1.220	1.285	1.269	1.338	1.364	1.306
	vs. Empirical	-0.352	-0.065	-0.320	-0.134	-0.093	-0.028	-0.018	-0.337
	vs. Baseline	-0.135	-0.166	-0.176	-0.189	-0.174	-0.151	-0.111	-0.073

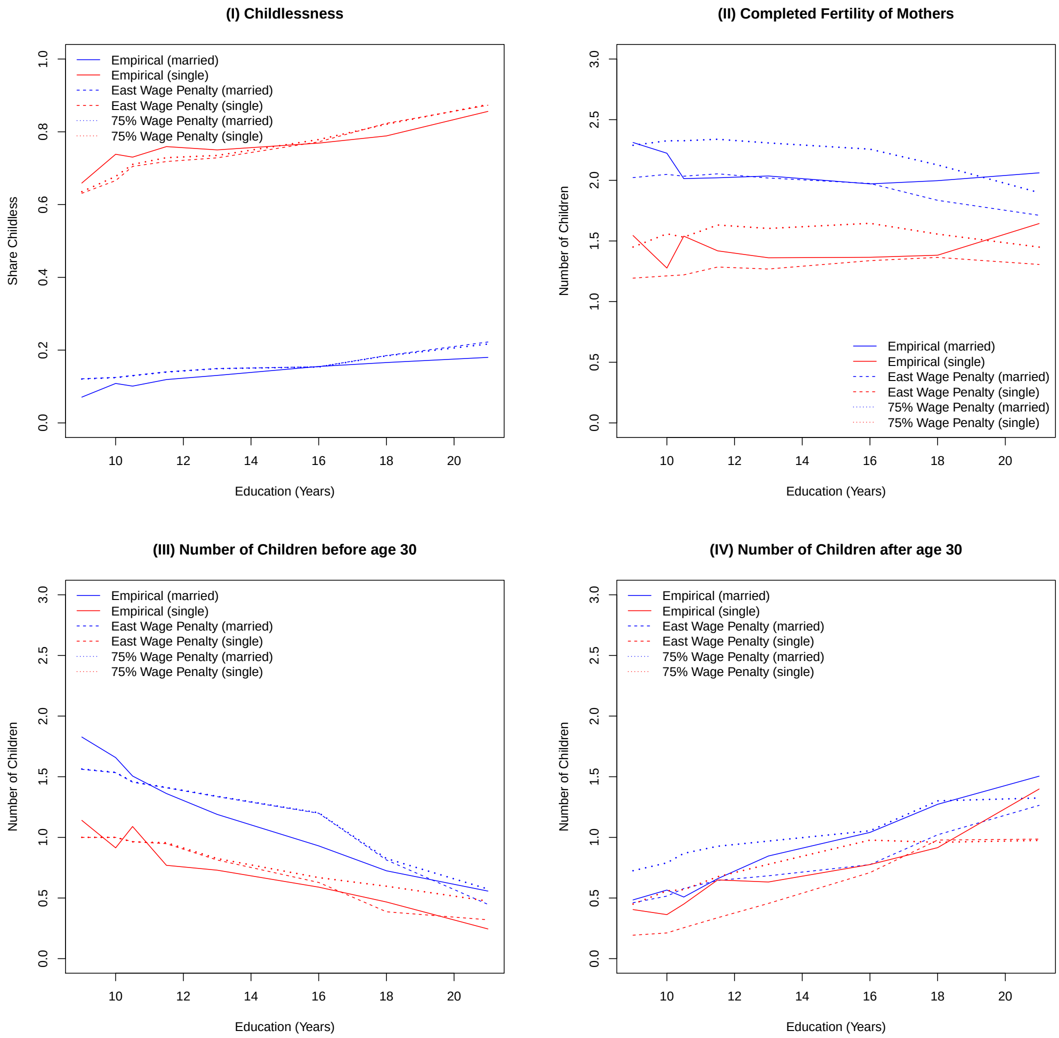
Note: Application of the East German wage penalty to West Germany. VS.-rows are calculated by subtracting empirical values / baseline simulation results from the counterfactual results. Values rounded.

Table A.19: Effect of a 25 % Reduction in the Wage Penalty for West Germany (ϵ)

		1	2	3	4	5	6	7	8
Childlessness (married)	Value	0.121	0.124	0.130	0.140	0.149	0.154	0.184	0.217
	vs. Empirical	0.050	0.016	0.029	0.021	0.019	-0.001	0.018	0.037
	vs. Baseline	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.003
Childlessness (single)	Value	0.635	0.677	0.710	0.729	0.735	0.779	0.821	0.875
	vs. Empirical	-0.024	-0.061	-0.020	-0.030	-0.015	0.010	0.032	0.019
	vs. Baseline	0.003	0.004	0.001	0.005	0.005	0.004	-0.001	0.001
Fertility (married)	Value	2.289	2.326	2.326	2.339	2.308	2.257	2.127	1.898
	vs. Empirical	-0.023	0.102	0.312	0.318	0.273	0.286	0.130	-0.163
	vs. Baseline	0.131	0.136	0.135	0.138	0.147	0.142	0.137	0.090
Fertility (single)	Value	1.450	1.559	1.532	1.632	1.603	1.645	1.557	1.449
	vs. Empirical	-0.095	0.282	-0.008	0.213	0.242	0.280	0.174	-0.194
	vs. Baseline	0.121	0.181	0.135	0.157	0.160	0.156	0.081	0.070

Note: Simulation of a 25 % reduction in the wage penalty to West Germany. VS.-rows are calculated by subtracting empirical values / baseline simulation results from the counterfactual results. Values rounded.

Figure A.4: Application of Alternative Wage Penalties to West Germany



Notes: Counterfactual Simulation - Simulating changes in the wage penalty (ϵ). Lines are the empirical moments observed in the data, dashed lines are simulation results for the application of the East German wage penalty (ϵ), dotted lines are the simulation results for a 25% decrease in the wage penalty (ϵ) to West Germany. *Data*: German Microcensus, survey years 2008 & 2012, own calculations.

Table A.20: Reasons for Childlessness (East German ϵ / 25 % Reduction in ϵ)

	East Germany ϵ						25% Reduction of ϵ					
			Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness	
Education	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement
1	0.821	0.179	0.378	0.622	0.704	0.296	0.818	0.182	0.366	0.634	0.704	0.296
2	0.832	0.168	0.401	0.599	0.656	0.344	0.830	0.170	0.392	0.608	0.656	0.344
3	0.820	0.180	0.436	0.564	0.579	0.421	0.818	0.182	0.428	0.572	0.579	0.421
4	0.788	0.212	0.402	0.598	0.504	0.496	0.785	0.215	0.394	0.606	0.505	0.495
5	0.797	0.203	0.413	0.587	0.502	0.498	0.793	0.207	0.407	0.593	0.506	0.494
6	0.787	0.213	0.419	0.581	0.462	0.538	0.787	0.213	0.416	0.584	0.466	0.534
7	0.799	0.201	0.407	0.593	0.331	0.669	0.798	0.202	0.406	0.594	0.334	0.666
8	0.809	0.191	0.369	0.631	0.289	0.711	0.816	0.184	0.368	0.632	0.309	0.691

Note: Reasons for childlessness by women's education. Sample restricted to women/couples who are childless. Left block for the application of the East German ϵ to West Germany, right block for the application of 25% reduction of ϵ to West Germany. Values within one line per sub-block add up to one. The blocks "Voluntary Childlessness" and "Involuntary Childlessness" contain the sub-groups of "Voluntary" and "Involuntary", respectively. Values rounded.

Table A.21: Reasons for Childlessness (East German ϵ for West Germany , Sub-Samples)

	All Childless Women						Single Childless Women						Married Childless Women					
			Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness	
Education	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement
1	0.821	0.179	0.378	0.622	0.704	0.296	0.996	0.004	0.988	0.012	1.000	0.000	0.740	0.260	0.000	1.000	0.702	0.298
2	0.832	0.168	0.401	0.599	0.656	0.344	0.993	0.007	0.981	0.019	1.000	0.000	0.748	0.252	0.000	1.000	0.652	0.348
3	0.820	0.180	0.436	0.564	0.579	0.421	0.990	0.010	0.982	0.018	0.857	0.143	0.721	0.279	0.000	1.000	0.573	0.427
4	0.788	0.212	0.402	0.598	0.504	0.496	0.994	0.006	0.960	0.040	1.000	0.000	0.686	0.314	0.000	1.000	0.499	0.501
5	0.797	0.203	0.413	0.587	0.502	0.498	0.990	0.010	0.955	0.045	0.714	0.286	0.693	0.307	0.000	1.000	0.499	0.501
6	0.787	0.213	0.419	0.581	0.462	0.538	0.982	0.018	0.922	0.078	0.214	0.786	0.676	0.324	0.000	1.000	0.470	0.530
7	0.799	0.201	0.407	0.593	0.331	0.669	0.985	0.015	0.840	0.160	0.125	0.875	0.679	0.321	0.000	1.000	0.337	0.663
8	0.809	0.191	0.369	0.631	0.289	0.711	0.992	0.008	0.691	0.309	0.250	0.750	0.668	0.332	0.000	1.000	0.290	0.710

Note: Reasons for childlessness by women's education. Sample restricted to women/couples who are childless in the counterfactual for the application of the East German ϵ to West Germany. Left block contains all women, the middle block all single women and the right block all married women, who are childless. Values within one line per sub-block add up to one. The blocks "Voluntary Childlessness" and "Involuntary Childlessness" contain the sub-groups of "Voluntary" and "Involuntary", respectively. Values rounded.

Table A.22: Reasons for Childlessness (25 % Reduction in ϵ & ϕ for West Germany , Sub-Samples)

	All Childless Women						Single Childless Women						Married Childless Women					
			Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness				Voluntary Childlessness		Involuntary Childlessness	
Education	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement	Voluntary	Involuntary	Constrained	Optimal	Sterility	Postponement
1	0.813	0.187	0.407	0.593	0.809	0.191	0.996	0.004	0.991	0.009	1.000	0.000	0.721	0.279	0.000	1.000	0.808	0.192
2	0.832	0.168	0.451	0.549	0.790	0.210	0.993	0.007	0.989	0.011	1.000	0.000	0.733	0.267	0.000	1.000	0.787	0.213
3	0.839	0.161	0.489	0.511	0.807	0.193	0.991	0.009	0.995	0.005	1.000	0.000	0.731	0.269	0.000	1.000	0.803	0.197
4	0.821	0.179	0.454	0.546	0.784	0.216	0.991	0.009	0.986	0.014	1.000	0.000	0.716	0.284	0.000	1.000	0.780	0.220
5	0.827	0.173	0.474	0.526	0.763	0.237	0.992	0.008	0.988	0.012	1.000	0.000	0.716	0.284	0.000	1.000	0.759	0.241
6	0.823	0.177	0.486	0.514	0.708	0.292	0.996	0.004	0.965	0.035	1.000	0.000	0.700	0.300	0.000	1.000	0.705	0.295
7	0.813	0.187	0.485	0.515	0.476	0.524	0.997	0.003	0.898	0.102	0.667	0.333	0.668	0.332	0.000	1.000	0.474	0.526
8	0.800	0.200	0.432	0.568	0.347	0.653	0.993	0.007	0.719	0.281	0.333	0.667	0.619	0.381	0.000	1.000	0.347	0.653

Note: Reasons for childlessness by women's education. Sample restricted to women/couples who are childless in the counterfactual for the application of a 25% reduction in ϵ to West Germany. Left block contains all women, the middle block all single women and the right block all married women, who are childless. Values within one line per sub-block add up to one. The blocks "Voluntary Childlessness" and "Involuntary Childlessness" contain the sub-groups of "Voluntary" and "Involuntary", respectively. Values rounded.

Table A.23: Effect of a 25% Increase in Wage Penalty for Germany (ϵ)

		1	2	3	4	5	6	7	8
Childlessness (married)	Value	0.082	0.064	0.063	0.064	0.069	0.070	0.090	0.118
	vs. Baseline	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Childlessness (single)	Value	0.599	0.631	0.658	0.651	0.666	0.692	0.788	0.834
	vs. Baseline	-0.002	0.002	0.002	-0.003	-0.002	0.000	0.001	-0.000
Fertility (married)	Value	2.629	2.622	2.605	2.575	2.578	2.568	2.474	2.249
	vs. Baseline	-0.058	-0.053	-0.056	-0.057	-0.053	-0.055	-0.060	-0.055
Fertility (single)	Value	1.284	1.361	1.323	1.388	1.344	1.315	1.420	1.449
	vs. Baseline	-0.058	-0.048	-0.056	-0.071	-0.057	-0.072	-0.057	-0.049

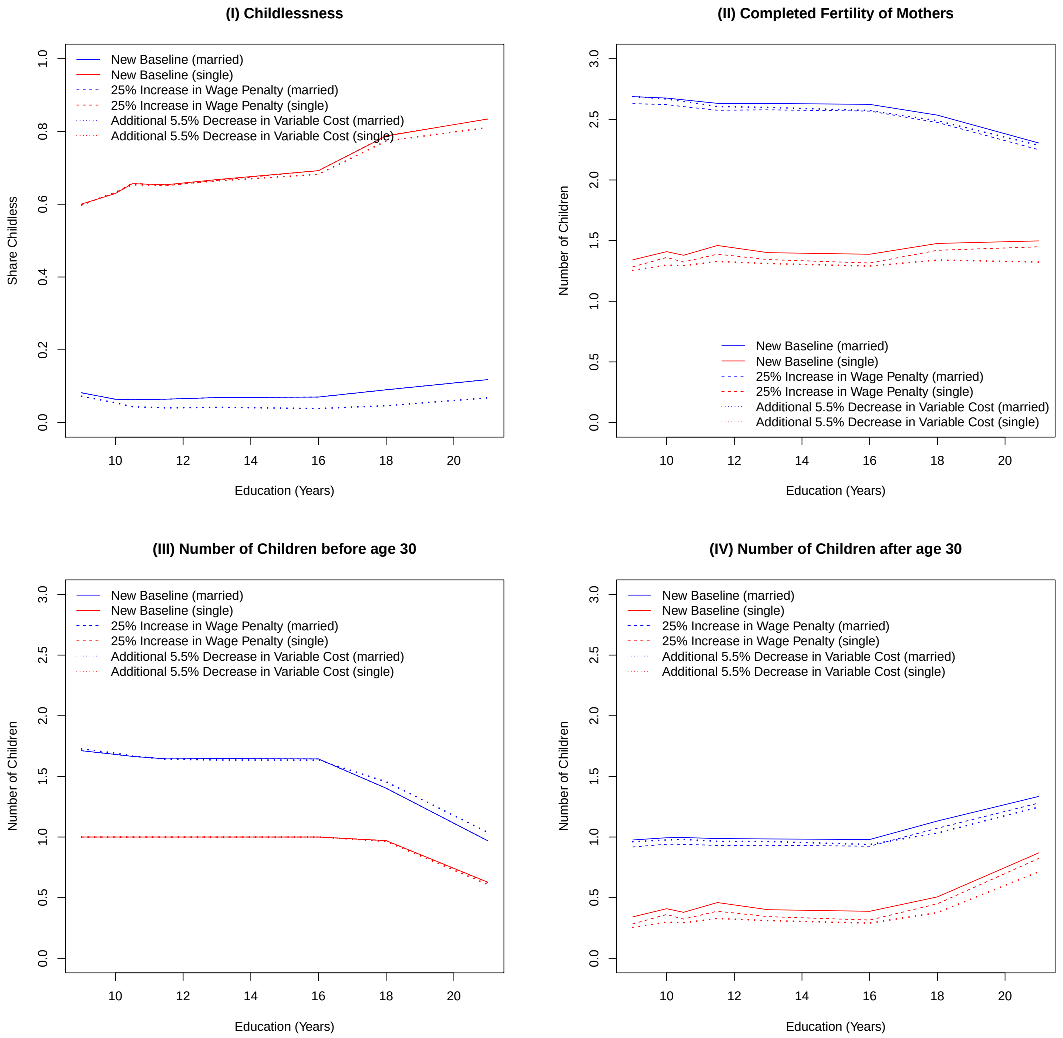
Note: Application of a 25% increase in the wage penalty for Germany.Germany is the new baseline with East German cost for children in period 1 (η_1) and West German wage penalty (ϵ). VS.-rows are calculated by subtracting the new baseline simulation results from the counterfactual results. Values rounded.

Table A.24: Additional Effect of a counteracting 5.5% decrease in Variable Cost of Children (ϕ) for Germany

		1	2	3	4	5	6	7	8
Childlessness (married)	Value	0.072	0.054	0.044	0.040	0.042	0.038	0.046	0.068
	vs. Baseline	-0.009	-0.010	-0.019	-0.024	-0.027	-0.032	-0.044	-0.050
Childlessness (single)	Value	0.597	0.633	0.653	0.652	0.664	0.682	0.774	0.811
	vs. Baseline	-0.003	0.004	-0.003	-0.001	-0.004	-0.010	-0.014	-0.024
Fertility (married)	Value	2.688	2.667	2.647	2.606	2.598	2.573	2.489	2.285
	vs. Baseline	0.000	-0.008	-0.013	-0.026	-0.033	-0.050	-0.046	-0.019
Fertility (single)	Value	1.255	1.299	1.293	1.328	1.311	1.290	1.340	1.324
	vs. Baseline	-0.087	-0.111	-0.086	-0.131	-0.090	-0.097	-0.137	-0.174

Note: Application of a in 25% increase in the wage penalty and a counteracting 5.5% decrease in the variable cost of children for Germany. Germany is the new baseline with East German cost for children in period 1 (η_1) and West German wage penalty (ϵ). VS.-rows are calculated by subtracting the new baseline simulation results from the counterfactual results. Values rounded.

Figure A.5: Changes in Wage Penalty and Variable Cost of Children (all plots)



Notes: Counterfactual Simulation - Simulation of a 25% increase in the wage penalty (ϵ) and a counteracting 5.5% reduction in the variable cost of children (ϕ). Regular lines indicates the new baseline simulation, dashed lines illustrate the application of only a 25% increase in the wage penalty (ϵ) and dotted lines indicate an additional 5.5% reduction in the variable cost of children (ϕ).

A.8 Optimization Routines

The model parameter are estimated using a tree stage estimation procedure. First, a set of initial values of size 500,000 is drawn from the complete solution space for each parameter and the model is evaluated using this initial grid. Second, - based on the results from step one - a genetic (global optimization) algorithm is run using the best combinations of values from step one as starting values. The second step is used in order to find the area in the parameter space in which the global maximum lies. The final parameter values are obtained using the (local) Powell Optimization (PO) routine. Estimation steps one and two are performed at the Leibniz Supercomputing Centre of the Bavarian Academy of Science and Humanities (LRZ), while the last step (PO-Optimization) is performed on a local machine. All optimization routines have standard implementations in R, which I use. However, I have adjusted the genetic algorithm package in order to work with Rmpi communication based parallelization between computing nodes on the Leibniz Supercomputing Centre of the Bavarian Academy of Science and Humanities (LRZ).

A.8.1 Genetic Algorithm

The genetic algorithms R-package "GA" provides a valuable and flexible toolbox for general-purpose stochastic optimization of binary and real-valued functions. Genetic algorithms are stochastic optimization routines that work by mimicking biological evolution and natural selection. At the end of each iteration of the optimization the fittest individuals survive. Additional biological mechanisms of evolution, such as crossover between surviving individuals and random mutation are applied when generating the new population for the next round from the surviving population of the last round. Thus, GA's provide a powerful general purpose optimization strategy for complex problems where first order conditions are not available. GA is robust against local extrema and can thus be used in a setting where the existence of multiple local extrema can not be ruled out. Unfortunately, GA's are - similar to the biological evolution of life - relatively slow and thus require high computational cost and time until convergence is achieved.

A.8.2 Powell Optimization Algorithm

The R-package "powell" provides the R implementation of the Unconstrained Optimization by Quadratic Approximation (UOBYQA) Algorithm, originally developed under Fortran by Michael J. D. Powell (Powell (2002)). Powell's UOBYQA Algorithm is an iterative, numerical and derivative free optimization algorithm that minimizes the objective function within a trust region by constructing and minimizing a quadratic model at each iteration step.

A.9 Identification

In this section, I illustrate the identification of the structural model parameter. I use 64 moments along 8 dimensions to identify my 14 model parameter. In the following I change each structural model parameter individually, leaving the remaining parameter constant to illustrate how changes in one parameter affect the simulated moments.

A.9.1 μ and $\bar{m}_a$

Increases in the public household good (μ) as well as decreases in the mean of the non-labor income decrease the available consumption in the household. Figure A.6 plots the response of the simulated moments for a 20% increase in μ (dashed line / triangles) and a 20% decrease in $\bar{m}_a$. Both parameter influence childlessness and marriage rates in roughly the same way. However, the number of children born to single women, both before and after age 30, is affected differently by both parameters across education levels, which allows for parameter identification.

A.9.2 δ_f and δ_m

δ_f and δ_m affect both marriage rates as well as childlessness and the inter-temporal allocation of children of single women. Figure A.7 plots the response of the simulated moments for a 20% increase in δ_f (dashed line / triangles) and a 20% decrease in δ_m. The model parameter can be identified as both parameters affect both childlessness and the inter-temporal allocation of children for single women differently across education levels. Furthermore both parameter increase childlessness for single women but have different effects on marriage rates.

A.9.3 ϕ, η and η_2

The time cost of children ϕ and η affect both childlessness and the number of children born in each period. Figure A.8 plots the response of the simulated moments for a 20% increase in ϕ (dashed line / triangles) and a 20% decrease in η. The structural parameter affect childlessness differently by marital status and education level. The same is true for the number of children born before and after age 30 of the mother. This allows for model parameter identification.

The fixed time cost of children η and η_2 affect the number of children born in each period and the inter-temporal allocation of children. Figure A.9 plots the response of the simulated moments for a 20% increase in η (dashed line / triangles) and a 20% decrease in η_2. The parameter are identified via their different effect on the number of children per period by education group.

A.9.4 ν and β

The preference parameter allowing for zero children (ν) and the discount rate (β) enter the utility function directly. While the preference parameter is constant across periods and education groups, the discount rate affects individuals differently by education level due to the return to experience which depends on individuals education level. While both changes in parameter values have effects going in the same direction for childlessness and marriage rates, the effects differ for the number of children born before and after age 30 both by marital status and by education level. Figure A.10 plots the response of the simulated moments for a 20% increase in ν (dashed line / triangles) and a 20% decrease in β.

A.9.5 $\hat{c}$ and σ_a

Increases in the minimum consumption level for procreation ($\hat{c}$) and decreases the standard deviation of the non-labor income affect marriage rates in a similar way (yet of different sign). At the same time, both changes in parameter values decrease childlessness for married women across almost all education levels in a non-linear way. Furthermore, both parameter affect childlessness and the number of children born in each period in a substantially different way across marital status and education background. Figure A.11 plots the response of the simulated moments for a 20% increase in $\hat{c}$ (dashed line / triangles) and a 20% decrease in σ_a.

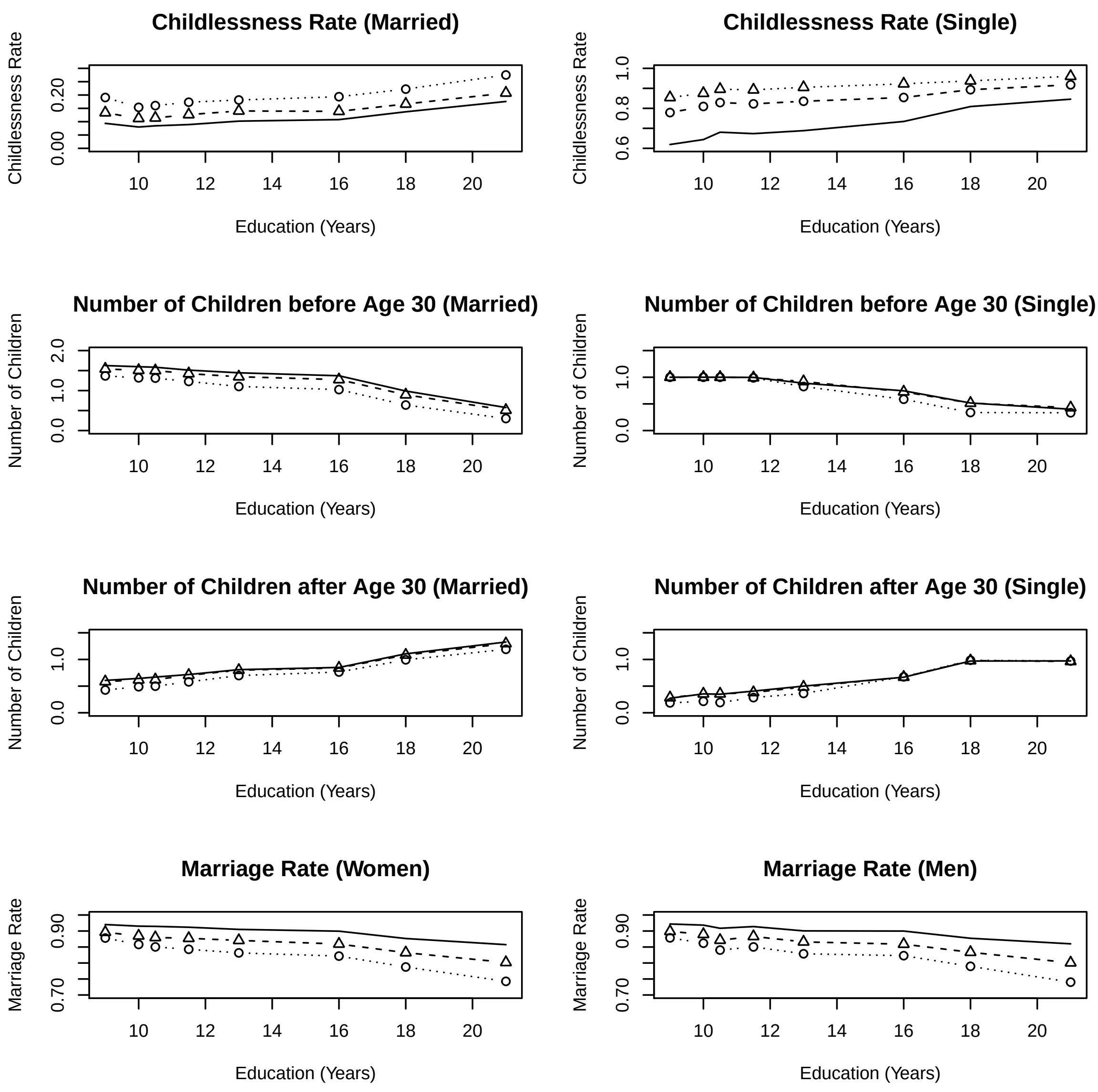
A.9.6 ω and ϵ

The level of assortative matching on the marriage market ω overall shows little effects compared to the negative wage effect of long term child-rearing ϵ. While ω mainly affects childlessness of single women and marriage rates, ϵ affects the timing of children in a way that strongly depends on mothers educational background and marital status. Furthermore, marriage rates of men are affected differently by education level. Figure A.12 plots the response of the simulated moments for a 20% increase in ω (dashed line / triangles) and a 20% decrease in ϵ.

A.9.7 α

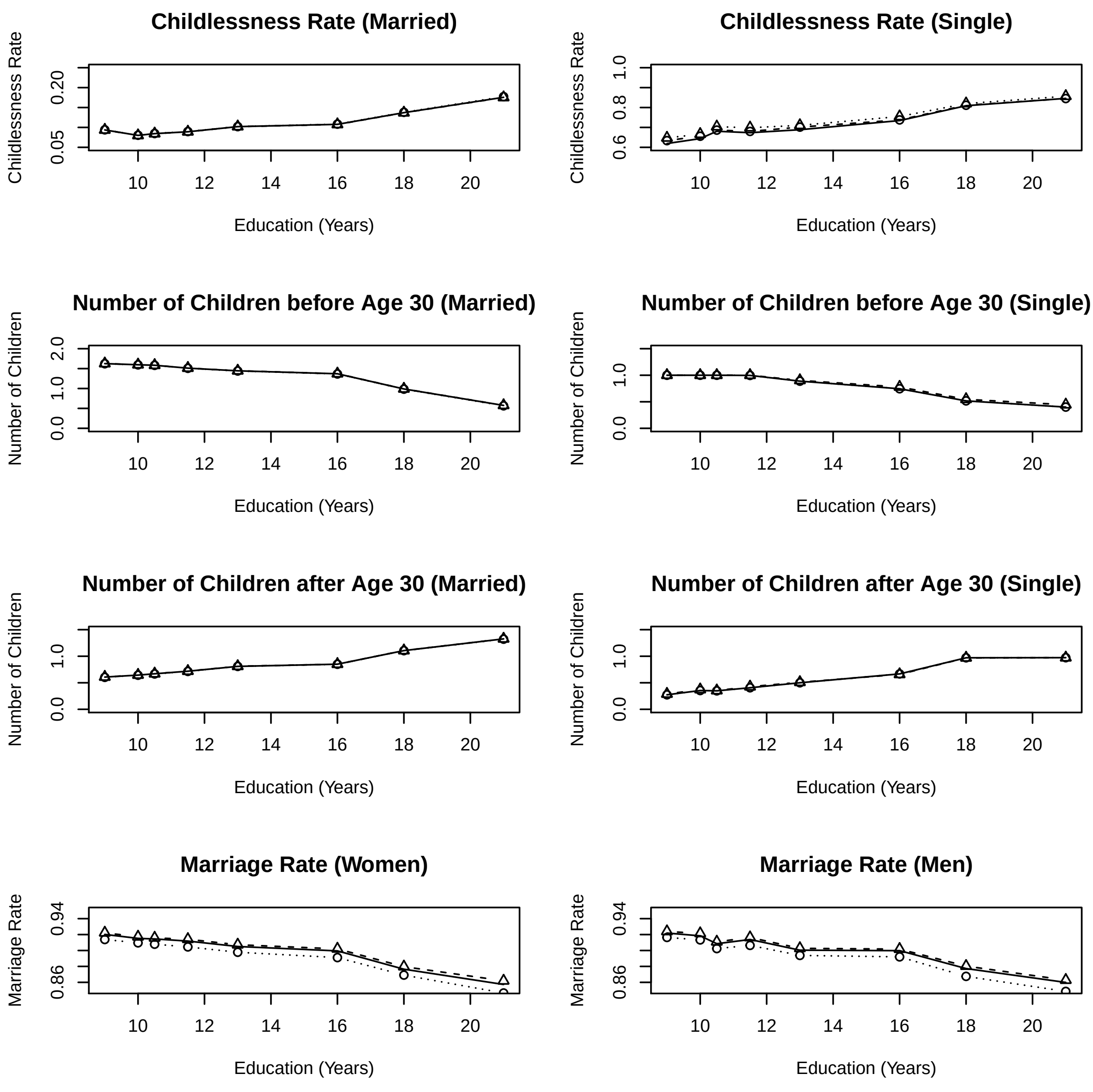
The share of child rearing provided by the husband only affects the fertility behavior of married couples and marriage rates. The extend to which α affects the optimal conditions depends on the relative income of both spouses, which varies by education level. In particular the number of children born after age 30 show heterogeneity in effect size by education level which allows for parameter identification. Figure A.13 plots the response of the simulated moments for a 20% increase in α (dashed line / triangles) and a 20% decrease in α.

Figure A.6: Identification of μ & $\bar{m}_a$



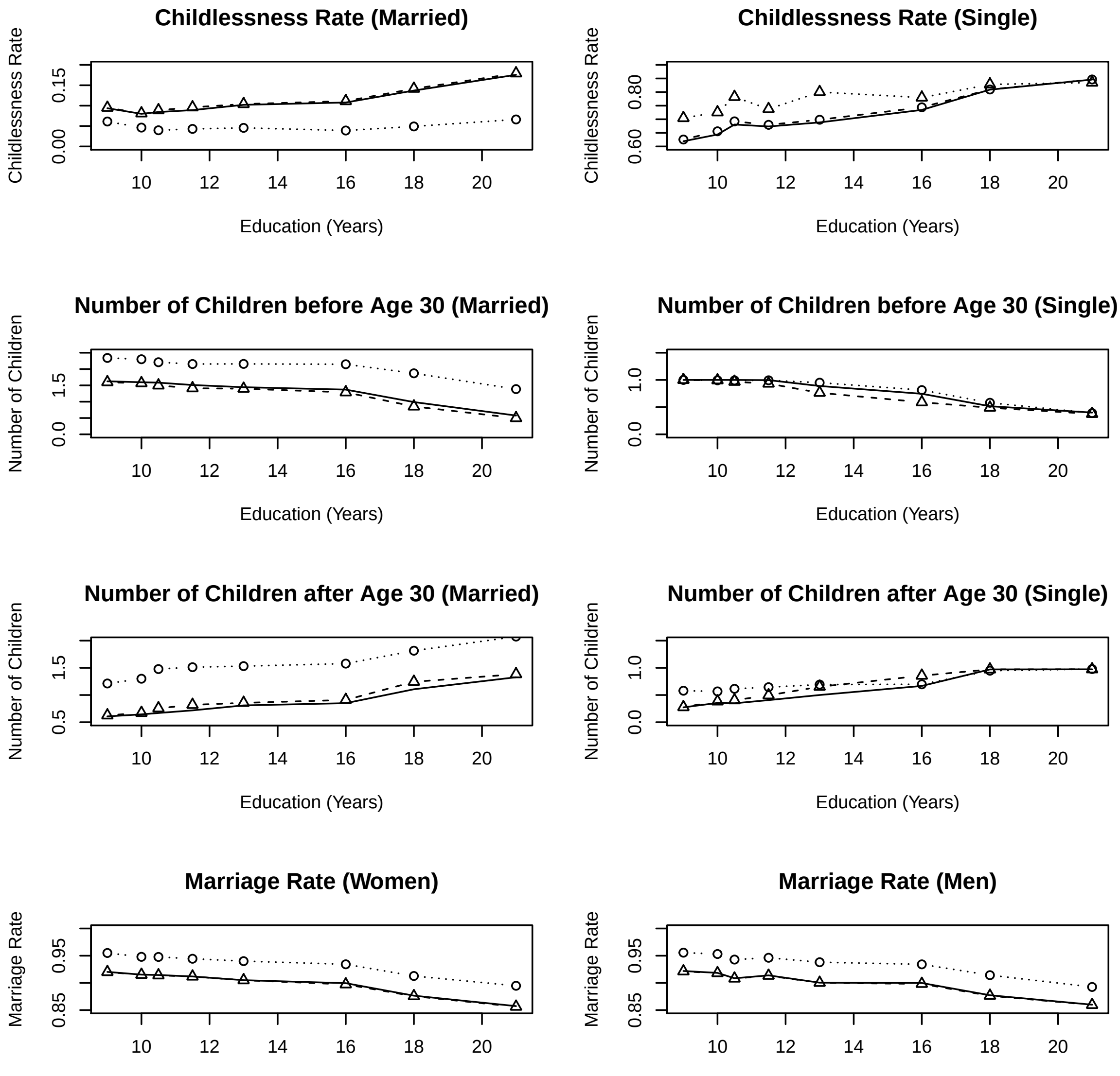
Notes: Identification of μ & $\bar{m}_a$ - Regular lines plot the baseline estimation results. Dashed lines/triangles symbolize a 20% increase in μ. Dotted lines/circles symbolize a 20% decrease in $\bar{m}_a$.

Figure A.7: Identification of δ_f & δ_m



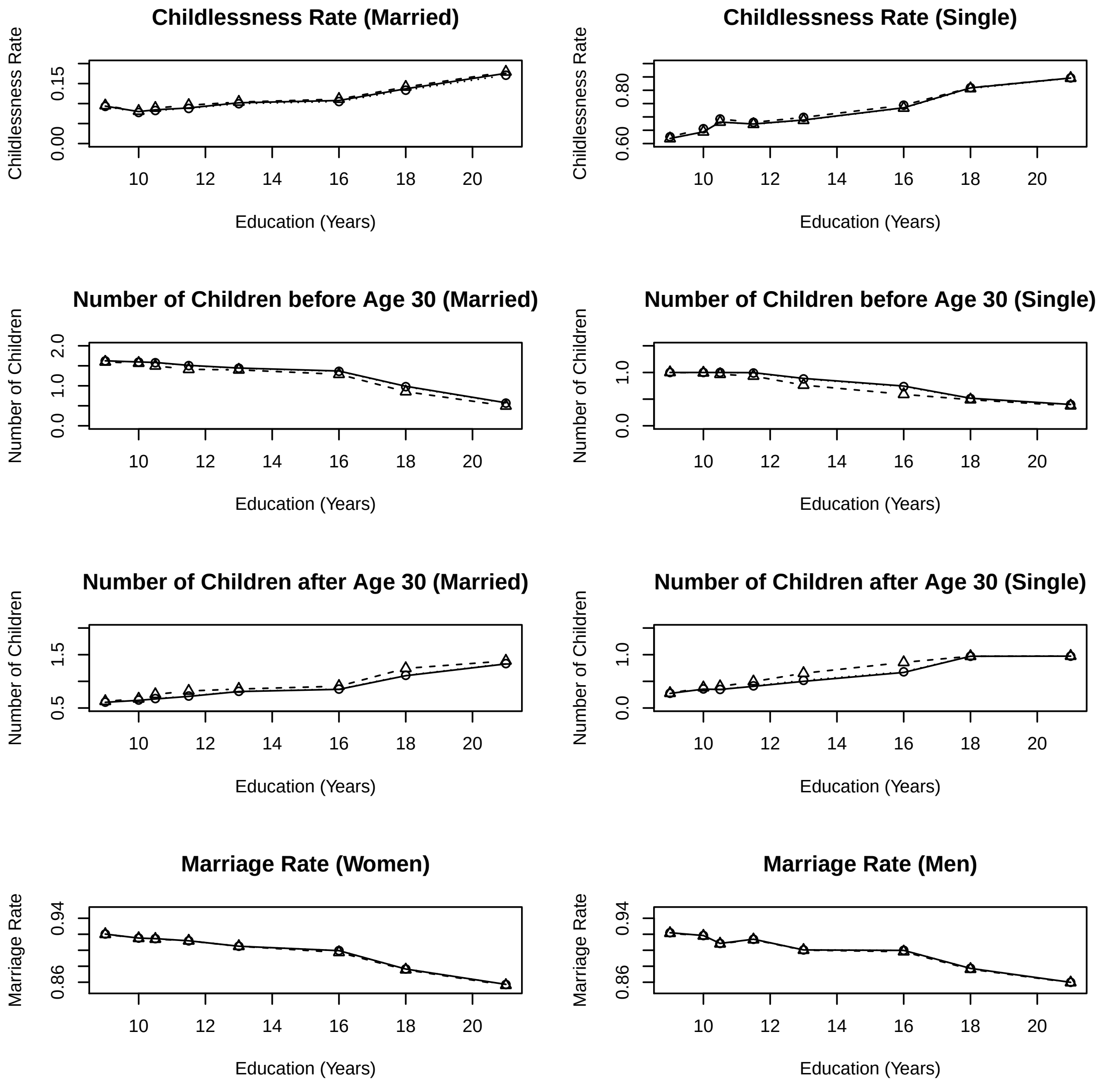
Notes: Identification of δ_f & δ_m - Regular lines plot the baseline estimation results. Dashed lines/triangles symbolize a 20% increase in δ_f. Dotted lines/circles symbolize a 20% decrease in δ_m.

Figure A.8: Identification of ϕ & η



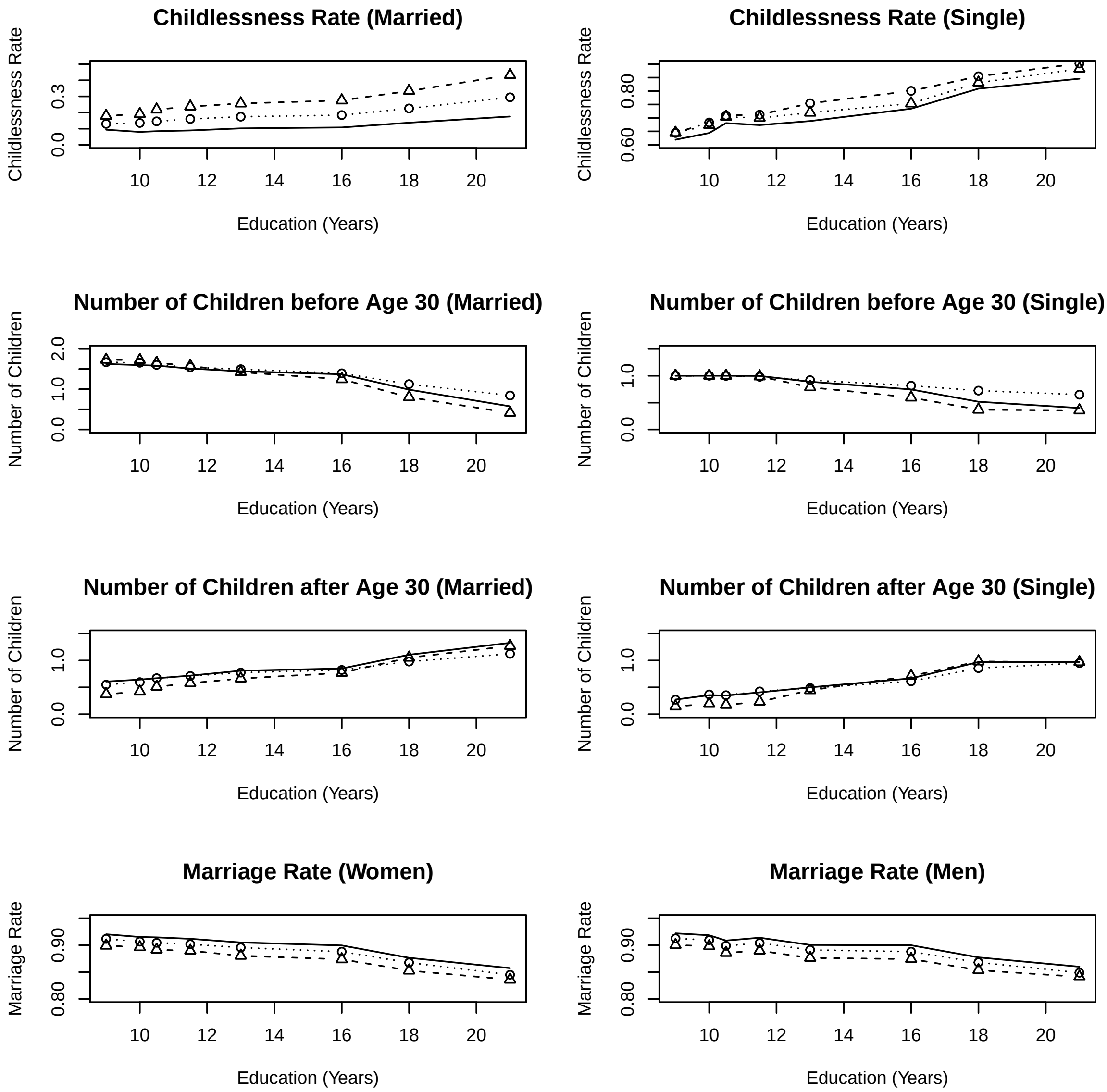
Notes: Identification of ϕ & η - Regular lines plot the baseline estimation results. Dashed lines/triangles symbolize a 20% increase in ϕ. Dotted lines/circles symbolize a 20% decrease in η.

Figure A.9: Identification of η & η_2



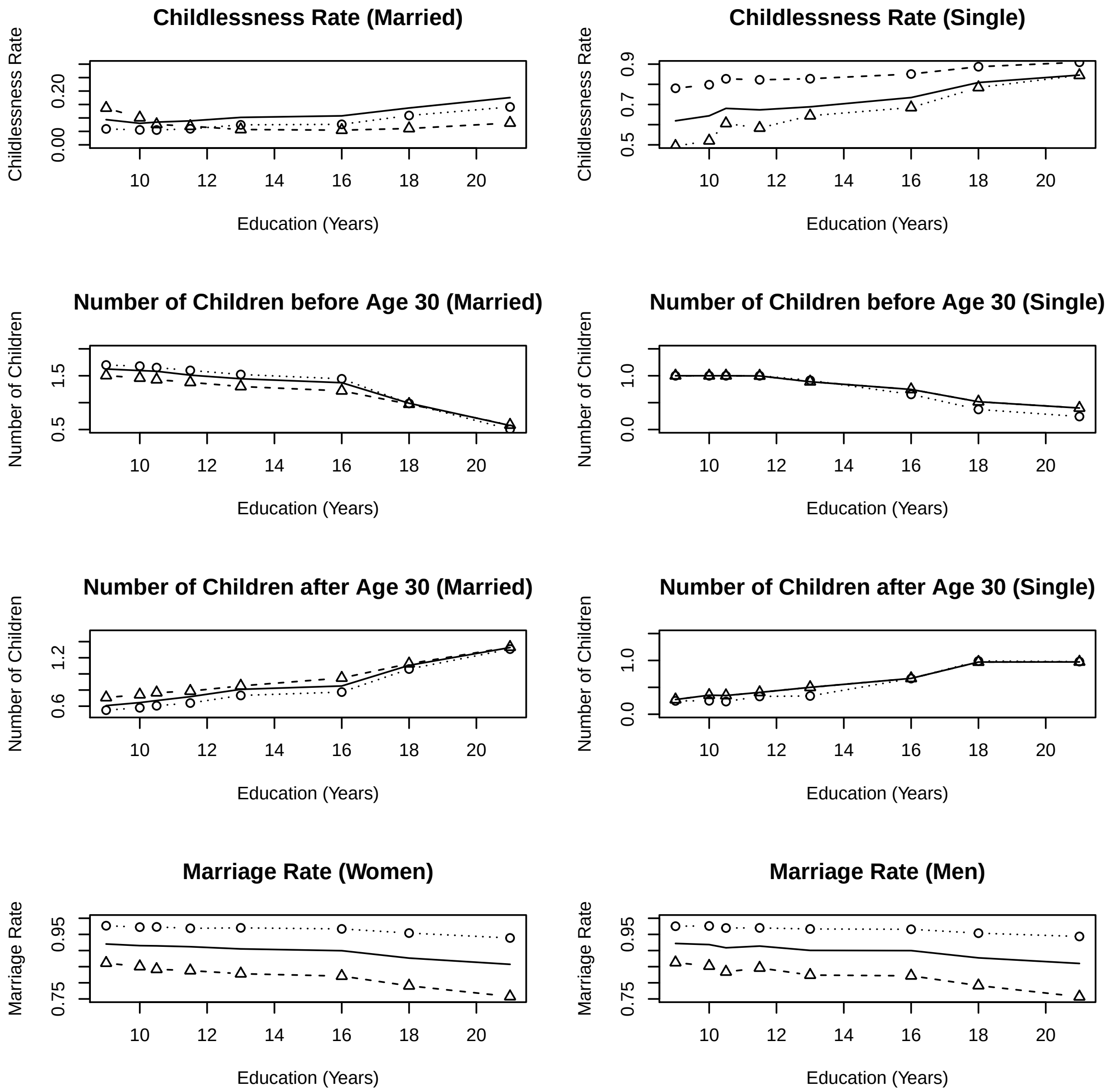
Notes: Identification of η & η_2 - Regular lines plot the baseline estimation results. Dashed lines/triangles symbolize a 20% increase in η. Dotted lines/circles symbolize a 20% decrease in η_2.

Figure A.10: Identification of ν & β



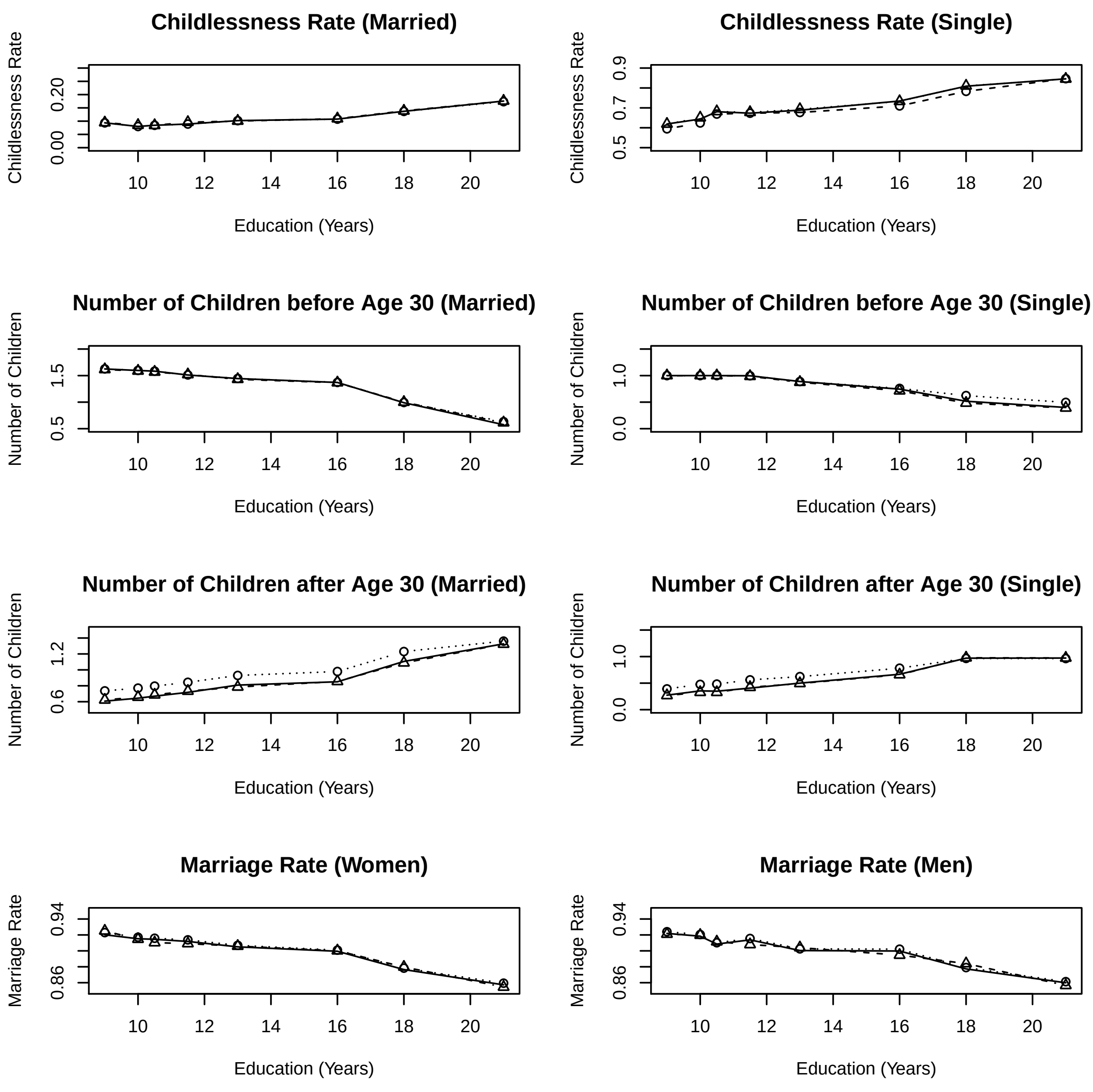
Notes: Identification of ν & β - Regular lines plot the baseline estimation results. Dashed lines/triangles symbolize a 20% increase in ν. Dotted lines/circles symbolize a 20% decrease in β.

Figure A.11: Identification of $\hat{c}$ & σ_a



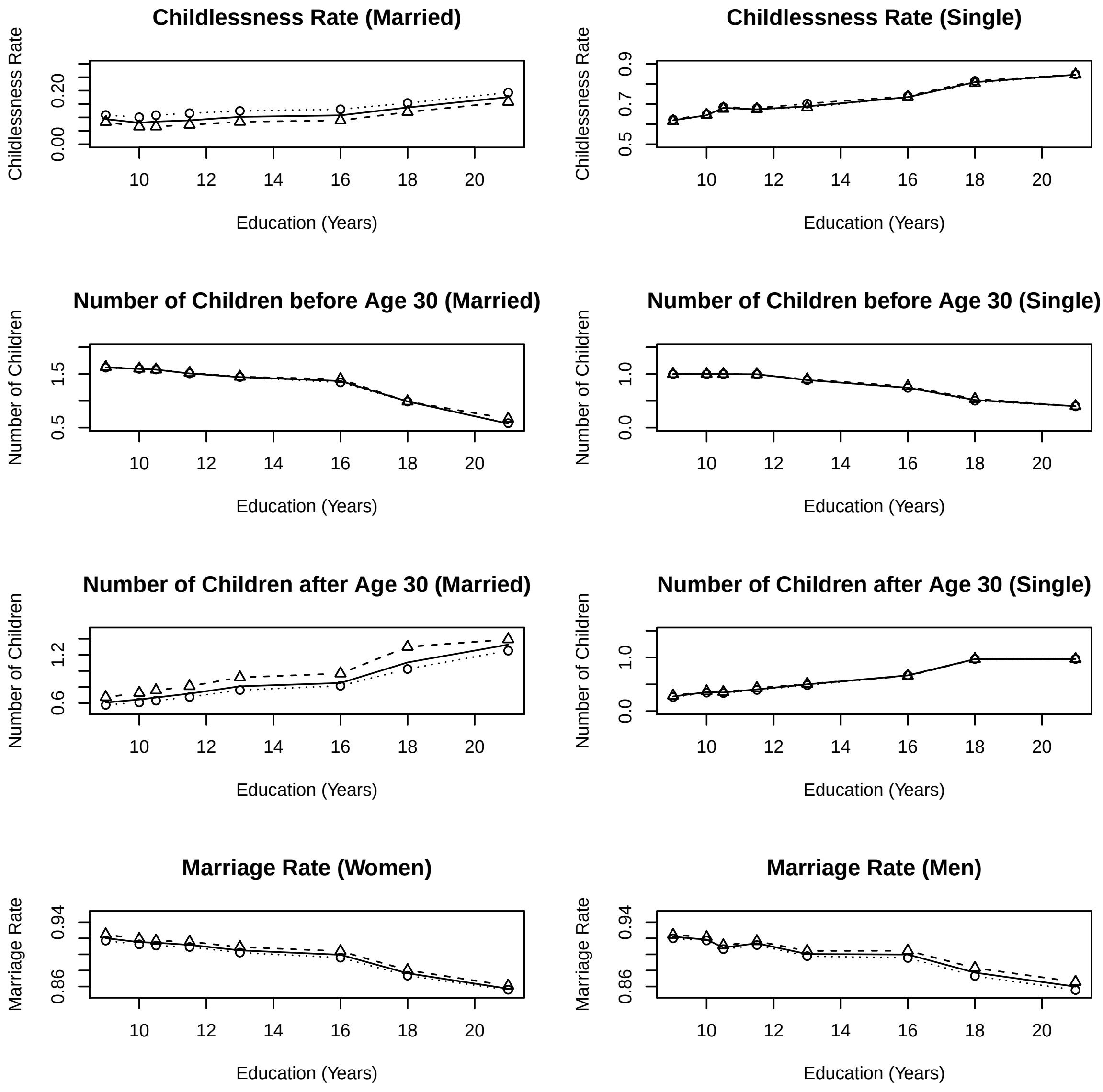
Notes: Identification of $\hat{c}$ & σ_a - Regular lines plot the baseline estimation results. Dashed lines/triangles symbolize a 20% increase in $\hat{c}$. Dotted lines/circles symbolize a 20% decrease in σ_a.

Figure A.12: Identification of ω & ϵ



Notes: Identification of ω & ϵ - Regular lines plot the baseline estimation results. Dashed lines/triangles symbolize a 20% increase in ω. Dotted lines/circles symbolize a 20% decrease in ϵ.

Figure A.13: Identification of α



Notes: Identification of α - Regular lines plot the baseline estimation results. Dashed lines/triangles symbolize a 20% increase in α. Dotted lines/circles symbolize a 20% decrease in α.