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Fertility and Childlessness in the United States†

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We develop a theory of fertility, distinguishing its intensive margin from its extensive margin. The deep parameters are identified using facts from the 1990 US Census: (i) fertility of mothers decreases with education; (ii) childlessness exhibits a U-shaped relationship with education; (iii) the relationship between marriage rates and education is hump-shaped for women and increasing for men. We estimate that 2.5 percent of women were childless because of poverty and 8.1 percent because of high opportunity cost of childrearing. Over time, historical trends in total factor productivity and in education led to a U-shaped response in childlessness rates while fertility of mothers decreased. (*JEL* I20, J13, J16, N31, N32)

Childlessness is an overlooked reality that cannot be explained by the current economic studies on fertility. At least three arguments show how important it is to distinguish between the extensive margin ($1 -$ childlessness rate) and the intensive margin (fertility of mothers) of fertility. The first follows from a historical analysis of the evolution of both margins. The top panel of Figure 1 shows that from one generation to another, the childlessness rate and the completed fertility of mothers can either be negatively or positively correlated, and that in the long run the relationship is surprisingly positive.[1] Our second argument comes from a cross-section analysis of these margins in 1990. The bottom panel of Figure 1 shows the relationship between childlessness and the completed fertility of mothers across education levels for a given cohort of American women (the sample is detailed in Section I). We see that there exists an education threshold $\underline{e}$ below which childlessness and fertility

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[1] A linear regression leads to a positive relationship between childlessness and the completed fertility of mothers over time.

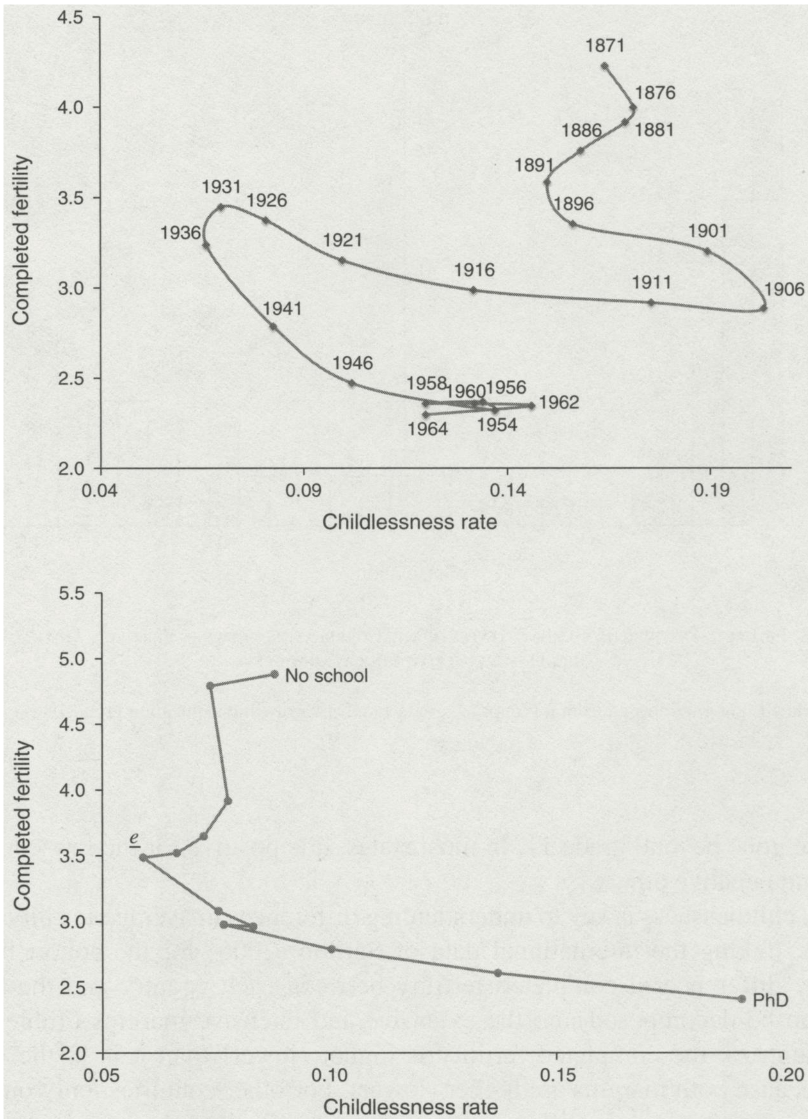

Figure 1. Completed Fertility of Mothers versus Childlessness (*Married women*) By Cohort (*Top panel*) and by Education Level (*Bottom panel*) in the United States

are positively correlated as education changes, while this correlation is negative above $\underline{e}$.

The nonmonotonic relationship is also visible when looking at state-specific data for the same sample. Figure 2 plots the histogram of the correlation between the completed fertility of mothers and childlessness at the state level in the United States. Frequencies in light gray concern the correlation across education levels between the completed fertility of mothers and childlessness for the group of women who have at the most completed grade 11. Frequencies in dark gray concern the group

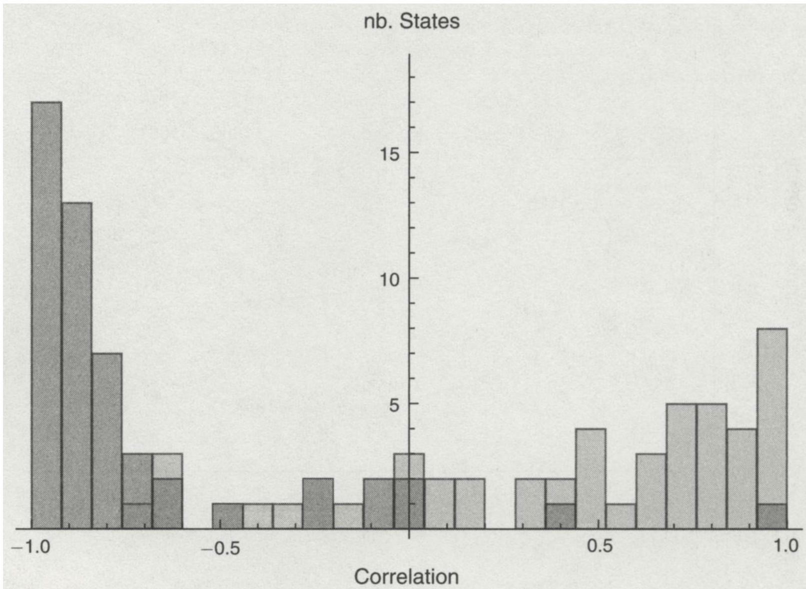

Figure 2. Distribution among States of the Correlation between Fertility and Childlessness across Education Levels

Notes: Light gray: low education groups (≤ grade 11). Dark gray: high education groups.

who have gone beyond grade 11. In most states, it is positive for the low-education group, and negative otherwise.[2]

Third, childlessness is key to understanding differences in average fertility across countries. Taking the international data of Sardon (2006) for the cohort born in 1955, the difference in completed fertility between each country and the United States can be decomposed into the extensive and intensive margins (Table 1). In some countries, the completed fertility is higher (lower) than it is in the United States because both margins are higher (lower). For other countries, only one margin explains cross-country differences in completed fertility. In Austria, Belgium, and Denmark, motherhood rates are higher than in the United States but total fertility is lower because mothers have fewer children. In France and Sweden, on the contrary, the fertility of mothers is similar to US levels, but motherhood rates are much higher. Hence, the driving force behind fertility differentials between France or Sweden and the United States for the 1955 cohort is childlessness. This confirms that both margins often play in opposite directions and that studying childlessness is necessary to understand international differences in fertility.

To summarize, the relationship between childlessness and fertility is not uniformly negative over time, across education groups, or across countries (which would be the case if childlessness was nothing more than low fertility). This reveals

[2] Online Appendix A.2.2 shows that for a majority of American states the relationship between completed fertility and childlessness is reversed between low- and high education levels, as in the bottom panel of Figure 1 for the United States as a whole.

Table 1—Decomposition of Completed Fertility Gaps into Intensive (*Fertility of mothers*) and Extensive Margins (*Motherhood*)

	Fertility decomposition		
	Gap with US	Intensive	Extensive
Austria	−10.2	−11.5	1.4
Belgium	−7.1	−8.3	1.2
Denmark	−6.6	−10.7	4.1
France	8.1	−1.3	9.4
Germany (W.)	−17.8	−13.6	−4.1
Ireland	35.5	30.7	4.8
Netherlands	−5.1	−4.4	−0.7
Norway	4.1	0.7	3.4
Sweden	3.0	−1.1	4.1
UK	2.0	1.4	0.6
Romania	15.7	6.5	9.3

Notes: We use the following decomposition: if $z = ab$, then $\frac{z - z'}{z} = \frac{a(b - b')}{z} + \frac{(a - a')b'}{z}$, where a and b, respectively, denote motherhood rates and the fertility of mothers.

that economic incentives do not always lead the two margins to respond in the same direction, as expected based on the previous literature on fertility decisions. As average fertility is composed of both margins, ignoring the specific determinants of childlessness can lead to unexpected consequences from a policy perspective. Hence, in this paper, we investigate what mechanisms make the extensive margin of fertility behave differently from the intensive margin, and how do economic changes affect these two margins.

To identify the relevant mechanisms behind variations in the two margins, we need more than the observation that fertility and childlessness could be positively correlated, as this could happen through a variety of channels. We therefore look at the education gradient of fertility, conditionally on fertility being positive, and of childlessness rates. We do so for both single and married persons, hence also considering marriage rates by education level. From US Census Bureau data for the year 1990 we find that: (i) the fertility of mothers decreases with education, for both married and single women; (ii) there is a U-shaped relationship between childlessness and education both for single and married women; and (iii) the relationship between marriage rates and education is hump-shaped for women and increasing for men (see Section I). To the best of our knowledge, the first two facts have not been documented for both single and married women before, and there is no theory which accounts simultaneously for these three facts.

Observations (i) and (ii) are strongly indicative of a fertility-education relationship in which fertility jumps from 0 to positive, and then declines. Understanding this discontinuity requires to posit a nonconvexity in the constraints faced by households, which is, in our case, a minimum consumption requirement to have children. The existence of high levels of childlessness among disadvantaged groups in the United States is described by McFalls (1979).[3] He argues that lower-income groups

[3]The negative relationship between social sterility and income has already been documented in Wolowyna (1977), for 1971 Canadian Census data. Romaniuk (1980) provides a good discussion of the existence of high levels of childlessness in very poor societies.

are more exposed to subfecundity causes (venereal diseases, malnutrition, psychopathological problems, environmental factors) than the rest of the population. The poor also have less access to quality medical services, which makes them more vulnerable to medical mistakes in abortions and cannot afford to buy fertilization services. Consequently, poor individuals are more affected by subfecundity factors because they do not have access to the same technologies as wealthier individuals.[4]

Individuals may therefore remain childless for three reasons. First, "natural sterility," can randomly affect any individual. Second, "social sterility," prevents poor women who do not have the minimum amount of commodities needed to procreate. Third, educated women who are not naturally sterile can remain childless because bearing and rearing a child takes time, and this opportunity cost is high for them in terms of foregone labor income. The U-shaped relationship between childlessness and the mother's education is driven by the coexistence of social sterility and of a high opportunity cost of parenting for educated women.

The model economy of this paper (Section II) is composed of men and women who play a two stage game. During the first stage, each individual is randomly matched with a partner of the opposite sex and decides whether to marry or not.[5] Second, after having discovered whether they are naturally sterile, couples and singles make decisions about consumption and, if they can, fertility. We assume a collective negotiation process (see Donni and Chiappori 2011 for a literature review) to model the behavior of households. As shown by Chiappori (1988), this framework has considerable empirical support.

Marriage entails costs and benefits. For men, it opens the possibility of having children. As a counterpart, some of their time will be allocated to child-rearing. For women, a husband alleviates the time cost of raising children. Marriage also generates economies of scale since spouses share the expenses of household public goods. Being in a relationship also allows saving time, which is particularly precious for highly educated people. The hump shaped relationship between marriage and education (Fact 2) is related to the high childlessness rates of uneducated and highly educated single women. For a man, marrying a woman who is too poor and requires help from the husband to procreate is less attractive. Marrying a woman with low incentive to have children (high opportunity cost) is hard as highly educated women reject marriage offers more often.

For simplicity, we abstract from unexpected births and cohabitation. Unwanted births are important from a social and individual point of view, as they can sharply reduce individual well-being. Bumpass and Westoff (1970) as well as Mosher, Jones, and Abma (2012) show that unwanted births concern mainly least educated women. Excluding these women from our dataset would then reinforce the U-shaped pattern of childlessness with respect to education.[6] Cohabitation covers

[4] Social sterility also covers situations in which living conditions are incompatible with raising a child. This includes poor, cramped, or unsafe housing that could put a small child at risk. In such case, women could have children from a purely biological standpoint but do not try to because of poor living conditions. The absence of pre- and postnatal care could also play the same role.

[5] To simplify, we assume the match is done randomly and that there is no second round. Results with a positive degree of assortative matching are given in online Appendix C.8.

[6] Unwanted first births can reduce childlessness rates as some women would not have children at all if they were able to perfectly control their fertility. Using data from the National Fertility Study (NFS), Bumpass and Westoff (1970) estimate that only 5 percent of first births were reported as unwanted between 1960 and 1965. Using data

two aspects: making decisions together, and/or receiving help from another person. Only the second aspect is taken into account in the model. For the period we consider, even though cohabitation was unlikely (Bumpass and Westoff 1970), so was single motherhood. Some of the women who are treated as single might then have an unmarried partner. In the United States of the 50s and the 60s, laws against cohabitation and premarital sex co-exist with laws against interracial marriage and no-fault divorce. Then, de facto, some situations of cohabitation (such as interracial unions) and out of marriage births cannot be legitimized by a marriage at this time. The 1990 US Census data enable us to go deeper on this issue (see online Appendix A.1 for details).

By abstracting from education choices, we implicitly take education as exogenous to marriage and fertility decisions. This simplification is based on the idea that education is decided first, but we acknowledge that in some cases causality could be reversed (see for example Rindfuss, Bumpass, and St. John 1980). For instance, women with a strong preference for children could choose to drop out of school to marry and have children. Our contribution should be understood as providing a unified theory of fertility, childlessness and marriage in the United States where we show the importance of education and income gradients. Alternative explanations remain possible and potentially relevant.[7]

The structural parameters of the model are identified using the three facts enumerated at the beginning (Section III). Average fertility decreases with mother's education, due to the higher opportunity cost of rearing children for more educated women. However, we show that Malthusian mechanisms, where education positively affects fertility, can appear for part of the population. As this positive effect concerns few individuals in the United States, we do not observe it on an aggregate level. We show, in online Appendix A.2.1, that this effect can be detected using historical aggregated data from Jones and Tertilt (2008) and also in regional and state-level data for the 1990 US Census. Concerning the U-shaped relationship between childlessness and education, we estimate that 2.5 percent of American women are socially sterile and 8.1 percent are childless because of the high opportunity cost.[8]

In a historical experiment (Section IV), we show that changes in education and in total factor productivity allow replicating the overall decreasing trend in fertility for the generations born between 1871 and 1964, while childlessness first decreased and then increased. We interpret the changes in childlessness first by a decline in childlessness created by poverty and, after the middle of the twentieth century, by an increase in childlessness created by a rise in the opportunity cost of having children.[9]

To the best of our knowledge, this paper constitutes the first study of the determinants of marriage and fertility along its two margins in a unified framework.

from the National Survey of Family Growth (NSFG) in 2002, Mosher, Jones, and Abma (2012) estimate that this percentage is 8.5 percent.

[7] If we were able to remove women having low education because they gave birth unexpectedly would however strengthen the U-shaped relationship between education and childlessness.

[8] With other data sources, alternative estimations of childlessness can be found in the literature. Using the National Survey of Family Growth for the year 1982, Mosher (1985) defines as "impaired fecund" women who are non-surgically sterile, for whom it is difficult or dangerous to have a baby, or who had a three-year or longer interval of formal or informal marriage and nonuse of contraception without a pregnancy. He estimates that 8.4 percent of American women 15–44 years of age were in such a case.

[9] With close arguments and through a cross-country analysis, Poston and Trent (1982) show the existence of a U-shaped relationship between the development level of a country and its childlessness rate.

Gobbi (2013) studies the determinants and the evolution of marital childlessness during the twentieth century. Aaronson, Lange, and Mazumder (2014) focus on a quantity-quality approach and look at how the Rosenwald Rural Schools Initiative in the early twentieth century affected fertility along both the extensive and intensive margins. They show, in particular, that the expansion of schooling opportunities decreased the price of child quality, which decreased the proportion of women with the highest fertility rates as well as childlessness rates. Both contributions assume that childlessness is always a choice. We differ from these papers by looking at the role played by the three sources of childlessness and marriage opportunities.

A growing literature is concerned both with family composition and fertility choices. However, it does not allow the three facts to all be explained together. Greenwood, Guner, and Knowles (2003) and Regalia, Ríos-Rull, and Short (2011) analyze both marriage and fertility decisions in a dynamic programming framework where individuals can divorce. Instead of increasing the complexity of their setup further to allow for different motives for childlessness, we develop a model abstracting from divorce and concentrating on the mechanisms behind fertility decisions.

I. Three Facts from the 1990 US Census

We use the 5 percent sample of the 1990 US Census, taken from the Integrated Public Use Microdata Series (IPUMS), and restrict our attention to the "ever-married, spouse present" and "never-married" women having completed their life-cycle fertility.[10] We look at women aged between 45 and 70 years old.[11] We divide the female population into 12 categories of education and report the corresponding average number of years of education, e, for each category as well as the unweighted number of observations (sum of singles and ever-married) per category. Table 2 summarizes the three stylized facts we focus on, computed using the weighted observations: completed fertility of mothers, childlessness rates of women, and marriage rates of men and women for 12 education levels.

FACT 1: *Fertility of mothers decreases with education, for both married and single women.*

This fact is well-known for married women. It is less known that, fertility of single women (conditionally on being mothers) also decreases with education. The negative relation between fertility and education has already been stressed in many papers without conditioning on both marital and motherhood status (see Becker 1981, pp. 150–51; de la Croix and Doepke 2003; and Jones and Tertilt 2008).[12]

[10] The 1990 census is the last one for the United States to report completed fertility for women that are older than 44 years old. We drop from our sample women who are separated, divorced, widowed, and married when their spouse is absent. The downward relationship between fertility of mothers and education and the U-shaped relationship between childlessness and education hold for these women as well. These categories account for 30.5 percent of women. We exclude them from the sample because we do not know since when they are no longer with their partner.

[11] The oldest and the youngest women of the sample have decided to marry and to become mothers in somewhat different social and economic conditions. As shown in online Appendix A.4, the facts presented in this section hold for each five-year cohort.

[12] See online Appendix A.3 for more details on the single mothers with little education.

TABLE 2—FACTS FROM THE 1990 US CENSUS

			Childlessness rates		Completed fertility of mothers		Marriage rates	
Education level	e	Observations	Married	Single	Married	Single	Women	Men
1. No school	0	12,122	0.088	0.755	4.880	3.897	0.699	0.716
2. Grade 1–4	3	14,050	0.074	0.590	4.791	3.810	0.836	0.864
3. Grade 5–8	7	84,243	0.078	0.631	3.916	3.480	0.909	0.909
4. Grade 9	9	38,121	0.072	0.560	3.647	3.419	0.933	0.924
5. Grade 10	10	57,213	0.066	0.588	3.519	3.324	0.945	0.928
6. Grade 11	11	49,413	0.059	0.524	3.485	3.430	0.948	0.934
7. Grade 12	12	479,703	0.076	0.781	3.079	2.549	0.948	0.937
8. 1 year of college	13	178,274	0.083	0.839	2.961	2.125	0.942	0.946
9. 2 years of college	14	53,428	0.077	0.825	2.976	2.257	0.945	0.946
10. Bachelor degree	16	99,046	0.101	0.934	2.788	1.944	0.916	0.934
11. Master degree	17	56,855	0.137	0.959	2.606	1.911	0.840	0.931
12. Doctoral degree	20	4,612	0.191	0.957	2.408	1.743	0.755	0.926
All		1,127,080	0.081	0.787	3.160	2.935	0.930	0.930

Notes: Standard errors are given in online Appendix A.5. Marriage rates of men are weighted (multiplied by 0.998, the ratio between the total number of married women and the total number of married men) in order to have an equal number of men and women in the data, as in the model. Each observation has a weight given by the census and represents between 2 and 186 individuals. These weights are used to compute the facts.

FACT 2: *Childlessness exhibits a U-shaped relationship with education for both single and married women.*

The relationship between childlessness and education is not monotonic unlike the relationship between fertility and education. As explained in the introduction, this U-shaped relationship is explained by the existence of both poverty and opportunity cost reasons leading to childlessness. As our model below illustrates, marriage is used as a way of insuring against social sterility for women with the lowest levels of education. This could explain why for married women, the U-shaped relationship looks more J-shaped. As shown in the bottom panel of Figure 1, there exists an education threshold for which childlessness is minimal (grade 11 for both singles and married). After this education threshold, childlessness increases with education. In our theory, this is due to the fact that highly educated women have a higher opportunity cost of raising children.[13]

FACT 3: *There is a hump-shaped relationship between marriage rates and education levels for women. Marriage rates (weakly) increase with education for men.*

Marriage rates are the highest for intermediate levels of education: from grade 5 to Bachelor degree, marriage rates are above 90 percent. For women, these rates

[13] For single women, the U-shaped pattern of childlessness with respect to education is robust if we merge the first three groups ("no school," "grade 1–4," and "grade 5–8"). Single women who are in the "no school" or "grade 5–8" group have an average childlessness rate that is significantly higher from the average rate of those in "grade 10." Childlessness rates of single women in all education groups are significantly different from that in "grade 11," except for those in "grade 9."

are lower for extreme levels of education: less than 70 percent for women with no education and 75 percent for women having a PhD. Marriage rates are low for lowly educated men (72 percent for those without any education) but remain high for the most educated.

Online Appendix A.6.1 shows that the three facts are true for whites, blacks, natives, Asians, and Hispanics separately. Online Appendix A.6.2 shows that the facts are also robust if we remove foreign born individuals from the sample, and hence do no rely on the behavior of foreigners who have made their marriage and fertility decisions in another country.

II. Theory

We consider an economy populated by heterogeneous adults, each being characterized by a triplet: sex $i = \{m, f\}$, wage w^i, and non-labor income a^i. Marriage is a two stage game. First, people enter the marriage market ignoring their sterility status and decide whether or not to marry the partner they have been randomly matched with; second, after having discovered their sterility status, they decide how much to consume and, eventually, how many children to have, if any. The utility of an individual of sex i is

$$u(c^i, n) = \ln(c^i) + \ln(n + \nu), \tag{1}$$

where c^i is the individual's consumption and n the number of children that he or she has. $\nu > 0$ is a preference parameter that allows for the existence of childlessness, as the individual utility remains defined when $n = 0$. Children are considered a public good for the couple and there are no gender differences in preferences. Assuming homogeneity in preferences, both across and within genders, is a way to measure by how much economic incentives account for our three stylized facts without relying on differences in preferences. Differences in fertility and childlessness result from the structure of the marriage market and the heterogeneity on labor and non-labor incomes.

Time endowment is to be shared between working and child rearing. This time equals 1 for a married person, and $1 - \delta^i$ for a single of sex i. This implies that marriage entails economies of scale in time (for instance, sharing domestic activities). Allowing for gender differences in the time endowment of singles does not only mean that women (or men) might be more productive in doing domestic tasks but also that there might be somebody else to help, in particular in the case of a single mother (a mother, a sister, a father, or a lover).

We assume that single women can have children whereas single men cannot. Having children entails time costs. First, there is a fixed cost, $\eta \in (0, 1)$ to becoming a parent. This is justified by the fact that the first child costs more in terms of time than the following children.[14] In addition, there is a variable cost: each

[14] Turchi (1975) estimates that the mean number of hours spent per day on childrearing for a one-child family is 1.4, for the first 18 years. For a two-child family it is 0.99 per child. And for a three-child family, it is 0.93. See Table 6.4 in Folbre (2008) for similar results.

child needs $\phi \in]0,1[$ units of time to be raised. When married, the husband bears an exogenous part $(1-\alpha) < 1/2$ of the childrearing time, as in Echevarria and Merlo (1999). If single, the mother has to bear the full time-cost alone. This makes single women more likely to be childless than married women.

To account for a positive degree of sterility among men and women that is uncorrelated to wealth, we assume that natural sterility is uniformly distributed over education categories. $\chi \in [0,1]$ and $\zeta \in [0,1]$ respectively describe the percentage of female and male who are naturally sterile. To model social sterility, we assume that in order to be able to give birth, a woman has to consume at least $\hat{c}$:

$$c^f < \hat{c} \Rightarrow n = 0. \tag{2}$$

This assumption has been amply justified in the introduction by the fact that lower-income groups are more exposed to causes of subfecundity than the rest of the population.[15] Each adult draws a non-labor income $a^i > 0$ from a distribution $\mathcal{F}^i(\overline{m}_a^i, \sigma_a^i)$, independent of his/her education. Non-labor income corresponds to the part of income that is uncorrelated with education.[16] The total non-labor income for a couple equals $a^f + a^m$. Wages per unit of time of men and women are respectively denoted w^f and w^m. Wages depend on education and gender only. Each household has to pay a goods cost, μ, which is a public good within the household. This type of cost is commonly assumed in the literature and gives some incentive to form couples (see Greenwood et al. forthcoming). The total non-labor income of the couple net of μ is denoted $a \equiv a^f + a^m - \mu$. Given these assumptions, the budget constraints, denoted as $b^m(c^m)$ for a single man, $b^f(c^f, n)$ for a single woman, and $b(c^f, c^m, n)$ for a couple, are as follows:

$$b^m(c^m) = c^m - (1-\delta^m)w^m - a^m + \mu \leq 0 \quad \text{and}$$

$$b^f(c^f, n) = c^f + \phi(1+\eta(n))\, w^f n - (1-\delta^f)w^f - a^f + \mu \leq 0,$$

$$b(c^f, c^m, n) = c^f + c^m + \phi(1+\eta(n))\left[\alpha w^f + (1-\alpha)w^m\right] n$$

$$- w^m - w^f - a \leq 0,$$

[15] Notice that, unlike a goods cost of children, $\hat{c}$ does not depend on the number of children that the mother will bear. A proportional goods cost does not imply social sterility, as the mother could choose a low enough number of children that is compatible with her budget constraint.

[16] As shown in Jones, Schoonbroodt, and Tertilt (2010), because of our log specification of the utility function, we need the non-labor income to be positive to generate the negative fertility-income relationship at the aggregate level. As mentioned by them, this could be gifts, lottery income, or bequests.

with the fixed time cost being given by

$$(3) \qquad \eta(0) = 0 \quad \text{and} \quad \eta(n) = \frac{\eta}{n} \text{ if } n > 0.$$

The maximum number of children a single, $\underline{n}_{\mathrm{M}}$, and a married, $\overline{n}_{\mathrm{M}}$, woman can have, given their respective time constraints, is

$$\underline{n}_{\mathrm{M}} = \frac{1 - \delta^f - \phi\eta}{\phi} \quad \text{and} \quad \overline{n}_{\mathrm{M}} = \frac{1 - \alpha\phi\eta}{\alpha\phi},$$

where $\overline{n}_{\mathrm{M}} > \underline{n}_{\mathrm{M}}$ because husbands help in the raising of children and marriage allows to save time.

To model couples' decision-making, we assume a cooperative collective decision model.[17] Spouses negotiate on c^m, c^f, and n. Their objective function is

$$U(c^f, c^m, n) = \theta(w^f, w^m)\, u(c^f, n) + (1 - \theta(w^f, w^m))\, u(c^m, n),$$

where $\theta(w^f, w^m)$ is the wife's bargaining power that depends on education and is given by

$$(4) \qquad \theta(w^f, w^m) \equiv \frac{1}{2}\underline{\theta} + (1 - \underline{\theta})\frac{w^f}{w^f + w^m}.$$

We specifically assume that the negotiation power of spouses is bounded from below, with a lower bound equal to $\underline{\theta}/2$, and positively related to their relative wage. As education will be used as a proxy for potential wages, negotiation power is in fact positively related to the relative education of the spouse.[18] The boundedness of the bargaining power function comes from the legal aspect of marriage: spouses have to respect a minimal level of solidarity inside marriage.

The different assumptions we have introduced imply some advantages to being married. It allows the cost of the household μ to be shared. It increases the time endowment of the participants by allowing to share domestic activities. Being married is the only way for men to have children. It allows women to reduce the opportunity cost of children (as long as $\alpha < 1$). Marriage gives at least one of the partners the opportunity to increase his/her consumption compared to the situation where he or she remains single.

[17] The fixed cost μ ensures that there is always a surplus coming from marriage. By adopting a collective cooperative decision model, rather than a Nash bargaining process where potential spouses share the marriage surplus, we avoid marriage rates being equal to one. With a Nash bargaining process, and no frictions in the marriage market, the only way to allow for some proportion of singles would be to assume some negative shocks on the quality of the matching.

[18] See de la Croix and Vander Donckt (2010) for a discussion. An alternative consists in assuming a negotiation power that depends on the spouses' relative labor income rather than their relative education as in Iyigun and Walsh (2007). As suggested by Pollak (2005), we have also tried a specification that included non-labor incomes in the bargaining power, results are provided in online Appendix C.6.

In order to write down the conditions under which a marriage offer from a randomly drawn person of the opposite sex is accepted, one needs to define the value functions of being ex post in one of the following situations:

$$V^{s,m} \equiv \{\max u(c^m, 0) \text{ such that } b^m(c^m) \leq 0\} \qquad \text{[single male]}$$

$$V^{s,f} \equiv \{\max u(c^f, n) \text{ such that } b^f(c^f, n) \leq 0, 0 \leq n \leq \underline{n}_{\mathrm{M}}, (2)\} \quad \text{[single female]}$$

$$\tilde{V}^{s,f} \equiv \{\max u(c^f, 0) \text{ such that } b^f(c^f, 0) \leq 0\} \qquad \text{[single sterile female]}$$

$$V^{\omega,i} \equiv u(c^i, n) \text{ where } \{c^f, c^m, n\} = \operatorname{argmax} U(c^f, c^m, n)$$

$$\text{such that } b(c^f, c^m, n) \leq 0, 0 \leq n \leq \bar{n}_{\mathrm{M}}, (2) \qquad \text{[married]}$$

$$\tilde{V}^{\omega,i} \equiv u(c^i, 0) \text{ where } \{c^f, c^m\} = \operatorname{argmax} U(c^f, c^m, 0)$$

$$\text{such that } b(c^f, c^m, 0) \leq 0 \qquad \text{[sterile married]}.$$

We now consider the decision to accept the marriage. Once a potential partner has been drawn, we know the vector (w^f, a^f, w^m, a^m). This allows each individual to compare his/her expected utility as a single and as a married person and decide whether to accept marriage or not. Marriage occurs if

$$(\chi + (1 - \chi)\zeta)\tilde{V}^{\omega,f} + (1 - \chi)(1 - \zeta)V^{\omega,f} \geq \chi\tilde{V}^{s,f} + (1 - \chi)V^{s,f},$$

$$(\chi + (1 - \chi)\zeta)\tilde{V}^{\omega,m} + (1 - \chi)(1 - \zeta)V^{\omega,m} \geq V^{s,m}.$$

We assume here that single women are not concerned with male sterility as they can have multiple sexual partners.[19] Married women are more concerned with natural sterility as they can be matched with a sterile partner.

The solutions to the maximization problems are provided in online Appendix B. Depending on which constraint binds, individuals can be in six different situations: [N] natural sterility, [S] social sterility when $c^f < \hat{c}$ and $n = 0$, [M] maximum fertility when the time constraint binds, [C] constrained fertility when $c^f = \hat{c}$ binds and $n > 0$, [O] opportunity cost driven childlessness when the constraint $n \geq 0$ binds, and finally, [U] unconstrained fertility.

We here describe how the fertility of a married woman depends on her education and the couple's non-labor income, keeping the husband's education fixed. A similar logic applies for a single woman (B.2). Abstracting from natural sterility [N], Figure 3 shows fertility decisions when the couple's non-labor income is low (top) and high (bottom). All the non-labor income thresholds A_1, A_2, A_5, and the wage thresholds $\mathcal{W}_A^f$, $\mathcal{W}_{\underline{C}}^f$, $\mathcal{W}_D^f$, $\mathcal{W}_F^f$, $\mathcal{W}_H^f$ are defined in online Appendix B.3. We see

[19] A woman who has n different sexual partners in her life meets only infertile partners with a probability ζ^n. If natural sterility among males is 5 percent and a woman has only two different partners in her lifetime, she has a probability of 0.0025 of meeting only infertile partners. According to the National Survey of Family Growth (2002), the average number of lifetime sex partners for women who have always been single in the United States is 7.44.

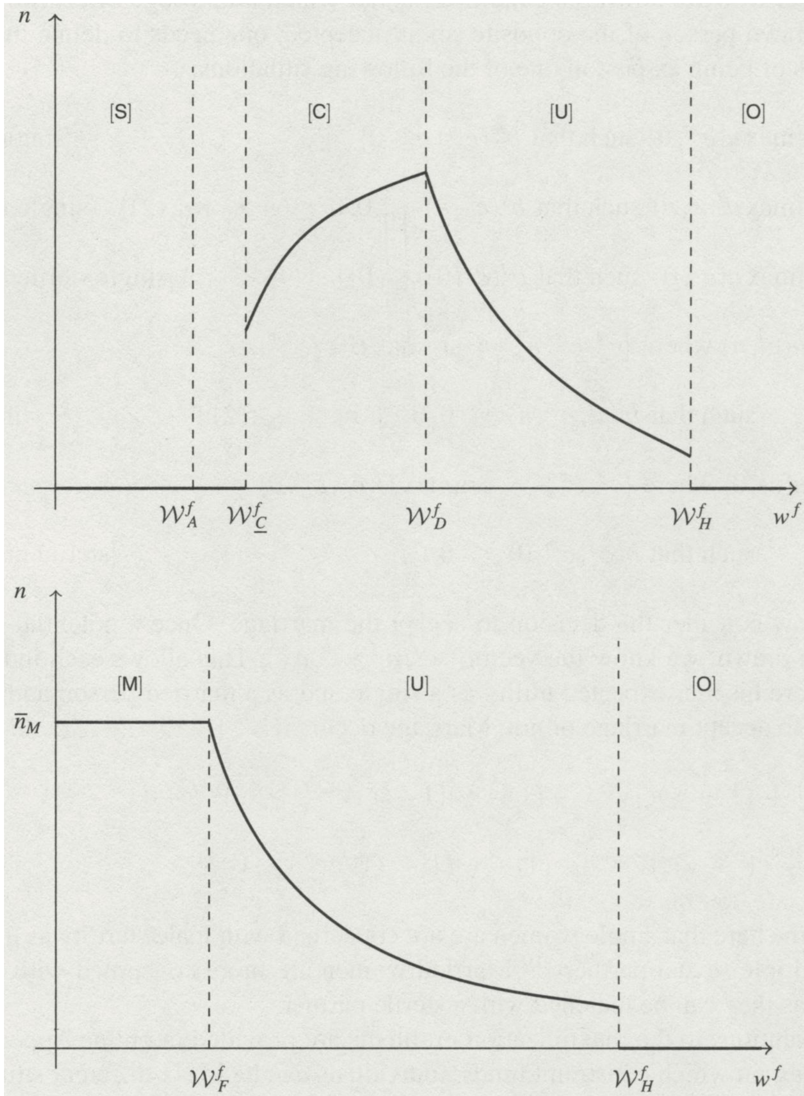

Figure 3. Fertility Conditional on Being Married when $a \in]A_1, A_2]$ and when $a > A_5$

that different non-labor incomes drive different fertility behaviors when female's wage is low. A woman with a very low wage ($w^f < \mathcal{W}^f_A$) in a marriage where the non-labor income is low ($a \in]A_1, A_2]$) cannot reach the minimal level of consumption that enables her to procreate. Hence, she is socially sterile [S]. When her education increases ($\mathcal{W}^f_A \leq w^f < \mathcal{W}^f_{\underline{c}}$), procreation is feasible but not optimal. For $\mathcal{W}^f_{\underline{c}} \leq w^f < \mathcal{W}^f_A$ fertility increases with female wage. In this Malthusian case [C], the minimal consumption constraint is binding with equality and an increase in female wages can affect fertility positively through an income effect. The Malthusian segment disappears as wealth increases. With a high non-labor income ($a > A_5$), women can always consume more than $\hat{c}$ and social sterility does not occur for any value of the female wage. A woman with a low wage has a low opportunity cost to childrear and it is optimal for the couple to have the maximal number of children [M]. An increase in the female wage implies a larger opportunity cost of childrearing in terms of foregone income and hence fertility decreases [U], up to the point when it is optimal to be childless [O].

According to Figure 3, a rise in non-labor income can reverse the relationship between education and fertility. This is consistent with Skirbekk (2008), who shows a general shift during the nineteenth century in Europe and North America from a positive to a negative relation between social status and fertility, and with Vogl (2014) according to whom, in developing countries, children from larger families had richer parents before 1960 and the opposite since then. Table 2 does not display the Malthusian positive relationship between fertility and education (top panel of Figure 3) as, nowadays, few American women have children while being in the constrained fertility case [C]. In Section II we estimate that 1.8 percent are in such a case. In order to see Malthusian mechanisms in aggregate US data, we need to look at historical as well as state level data. This is done in online Appendix A.2.1.

III. Identification of Parameters and Simulations

The model is now fit to match the facts provided in Table 2. There are in total 15 parameters. We first set a priori four of these parameters (wage equation and natural sterility), based on empirical information. The 11 remaining parameters are estimated using a minimum distance estimation procedure.

A. *A Priori Information*

Wages are computed as follows:

$$w_e = \gamma z \exp\{\rho e\}, \tag{5}$$

where e denotes the average number of years of education in each category (Table 2). The values of the gender wage gap γ and of the Mincerian rate of return to schooling ρ are estimated using census data (see online Appendix A.8.4 for details). The results lead to setting γ equal to 0.869 and ρ equal to 0.092.[20] z is a normalization factor that will be used in Section IVA to capture the trend in total factor productivity.

Normalizing wages with respect to the wage of a man who has a doctoral degree, the minimum wage equals 0.158 for men and 0.137 for women. The main drawback of the Mincerian approach is to assume the same return to schooling for all schooling levels. In online Appendix A.9, we discuss the importance of this assumption for our results. The asset of the Mincerian approach is to let income depend on two parameters only, γ and ρ, which can be the subject of counterfactual experiments. Such counterfactual exercises are provided in Section IVB.

[20] We assume that the gender wage gap γ is the same across education categories. Assuming that γ increases with education, as some studies in the 1980s suggested, modifies the results only marginally. Lips (2003) shows that this "education penalty" almost disappeared during the 1990s. The estimated value for the gender wage gap is similar to the estimates of Erosa, Fuster, and Restuccia (2010). The estimate of ρ is also in line with the literature (Krueger and Lindahl 2001).

The two sterility parameters, χ and ζ, are fixed using information from the literature on natural sterility. The ideal population to measure sterility among couples is one where marriage is associated with the desire to have children and where women marry young, do not divorce (e.g., because of sterility), are faithful to their husband, and live in a healthy environment. The closest to this ideal are the Hutterites. According to Tietze (1957), who studies sterility rates among this population, we should set the percentage of naturally sterile couples, $\chi + (1 - \chi)\zeta$, at 2.4 percent. Two alternative measures of sterility are discussed in online Appendix C.2. Our reading of the literature on the prevalence of fertility problems is that roughly half of them with a diagnosed cause are related to the man, and half to the woman.[21] We therefore set χ equal to ζ. The two restrictions lead to $\chi = \zeta = 1.21$ percent.

B. *Minimum Distance Estimates*

The 11 remaining parameters, listed in Table 3, are identified by minimizing the distance between 72 empirical and simulated moments. These moments are the completed fertility of mothers and childlessness rates among both singles and married women, and the marriage rates for women and men, for the 12 education categories listed in Table 2. The objective function to minimize is given by

$$f(p) = [d - s(p)][W][d - s(p)]',$$

where p is the vector of the parameters of the model, d denotes the vector of the empirical moments, and s the vector of the simulated moments, depending on the parameters. W is a weighting matrix with $1/d^2$ on the diagonal, and zero elsewhere.[22]

To compute the vector of the simulated moments, we proceed as follows. We draw 100,000 women for each category of education. Each woman draws a potential husband from the empirical distribution of education levels among men. Each individual (man and woman) also draws a non-labor income. We assume that the non-labor income follows a log-normal distribution of mean κ_a and variance σ_a^2. Writing $\kappa_a = \ln(\overline{m}_a \overline{w}) - \sigma_a^2/2$ where $\overline{w}$ denotes women's average wage, the parameter $\overline{m}_a$ can be interpreted as the average ratio of non-labor income to labor income. Then, for each category of education for women, we obtain 100,000 decisions about marriage and fertility that we can average to calculate the simulated moments.

We then minimize the objective function $f(p)$ (see implementation notes in online Appendix C.1). In the numerical implementation, we also assume that the number of births is an integer rather than a continuous variable. It does not alter the main mechanisms at play but simplifies computations (and is also realistic).

[21] This estimation is quite imprecise as definitions of sterility and infertility used in the literature lack uniformity (see Gurunath et al. 2011).

[22] This matrix is often used in the literature instead of the optimal weighting matrix, i.e., the inverse of the variance-covariance matrix of the empirical moments (Duffie and Singleton 1993). When using the optimal weighting the moments computed from a larger number of observations have lower standard errors and a higher weight. Consequently, for these moments, a higher distance between the data and the simulated moments is more heavily penalized in the objective function. In our case, using the optimal matrix lowers the weight of the observations for extreme education levels, which are the most useful for identification.

TABLE 3—IDENTIFIED PARAMETERS

Parameter		Value	SE
Variance of the log-normal distribution	σ_a	0.247	0.012
Average ratio of non-labor income to labor income	$\bar{m}_a$	1.001	0.012
Preference parameter	ν	9.362	0.146
Minimum consumption level to be able to procreate	$\hat{c}$	0.399	0.009
Good cost to be supported by a household	μ	0.272	0.013
Bargaining parameter	$\underline{\theta}$	0.864	0.014
Fraction of childrearing to be supported by women	α	0.524	0.005
Time cost of having children	ϕ	0.206	0.003
Fixed cost of children	η	0.114	0.006
Time cost of being single (men)	δ^m	0.256	0.015
Time cost of being single (women)	δ^f	0.077	0.013

C. *Results*

The identified parameters are listed in Table 3.[23] Non-labor income amounts on average to 100 percent of labor income. This number seems quite high, unless we interpret the non-labor income as including, gifts, bequests, capital income and transfers (including social security) that are not correlated with the education level of the recipient. To have an idea of the magnitude of σ_a, we computed a Gini coefficient on women's simulated life-cycle income, $w^f + a^f$, which came to 0.16. The estimated σ_a is relatively on the low side, but this is not surprising as some dimensions of inequality are absent from the model, such as wage dispersion for similar education levels.

To interpret the value of $\hat{c}$ and μ, remember that wages vary on a scale from 0.137 to 0.869 for women. For an average couple where both partners have 12 years of education and 2.5 children, the household cost represents 18 percent of consumption. This number is in line with the estimates found in Greenwood et al. (forthcoming). A single woman with the lowest wage will need a non-labor income higher than 0.548 ($\hat{c} + \mu - (1 - \delta^f - \phi\eta)w$) not to be socially sterile.

The minimum negotiation power of a spouse is $\underline{\theta}/2 = 0.432$. Alternative specifications for the bargaining power function θ have been tested. Online Appendix C.6 shows that fixing the bargaining power to 1/2 or making it depend on relative potential incomes (hence including non-labor incomes a^f and a^m) does not improve the matching with the data.

Spouses share childrearing time. We estimate that men are involved for 47.6 percent of this time. The interpretation of α should be broader than only active childcare spent by parents. Quoting Folbre (2008, p. 117): "Parents do more than merely devote time to their children. They work at the task of providing both active and passive care." Activities such as looking for care centers or schools, or cleaning the car, in which the parent is not directly with the child also enter the amount of time parents devote to their children. These activities are included in α but are hard to

[23] Online Appendix C.4 explains how the standard errors are computed. Online Appendix C.5 provides the identified parameters under the assumption that they are race specific, and that marriage markets are segmented by race. Online Appendix C.5 also gives the estimated parameters after having removed from the sample the "disables." A discussion of whether one should include them or not in the sample is provided in online Appendix A.7. Online Appendix C.5 also breaks down childlessness into its components for each subgroup.

estimate from surveys or time diaries. The values for ϕ and η imply that the first child costs $\phi(1 + \eta) = 22.9$ percent of the time endowment of one parent, while the second child costs 20.6 percent. Following the values of α, η, and ϕ, the maximum number of children that a married woman can raise is nine, while a single woman can have four children at most.

Our estimates of the δ^f and δ^m are such that $\delta^f < \delta^m$, implying that single women lose less time than single men because of their singleness. This can reflect the fact that women are more efficient at house keeping than men, or that single women find help more easily from others than single men. If we believe that singles have periods during which they cohabit with another person, the lower δ^f may also reflect that women benefit more from cohabitation than men. Notice finally that a positive δ^m is in line with the literature showing that married men are more productive (e.g., better health, higher wages) than single men (Korenman and Neumark 1991).

The simulated moments for the intensive and extensive margins of fertility that we obtain are represented in Figures 4 and 5. We reproduce the completed fertility pattern of single and married mothers (Fact 1), and the U-shaped relationship between childlessness and education for both married and single women (Fact 2). As for the marriage rates of men and women, Figure 6 shows that the model reproduces the hump-shaped relationship between marriage rates and education levels for women, and the positive correlation between marriage and education for men (Fact 3). For highly educated men, the high proportion of time they have to spend in rearing children (48 percent) implies that having children and being married is costly for them.[24] However, the 26 percent gain of time endowment by being married (δ^m) is enough to make them marry. The only weak aspect of the fit concerns the low education groups, for whom the theory overestimates the marriage rates by 10 to 18 percentage points.

As a test of the theory, we compare our results to empirical observations that were not used to identify the parameters. Looking at the fertility of married husbands is particularly interesting as it should allow us to assess whether our estimation of α is appropriate. Indeed, the slope of the relationship between the husband wage and fertility is determined by α (equation (2) in online Appendix B). Figure 7 reports the results. The theory reproduces the negative relationship between average fertility and the education of husbands with the right slope. This indicates that the opportunity cost for men of having children is adequately measured. Figure 7 also reports the childlessness rate of married men with respect to their education. The model also captures the U-shaped relationship between both variables.

Table 4 provides the proportion of women in each fertility situation, with respect to their education. Uneducated women are either socially sterile [S], with constrained fertility [C], or with the maximum number of children [M]. We estimate that 1.8 percent of American women are in this situation. This means that although aggregate fertility data suggests that Malthusian checks no longer prevail and Becker's model describes the negative relationship between education and fertility well, our model detects that some categories of the population are still affected by Malthusian

[24] Setting $\alpha = 1$ increases the marriage rates of highly educated men but the marriage rates of highly educated women are now strongly underestimated as they lose their incentive to marry and have children (we discuss this in more detail in online Appendix C.7).

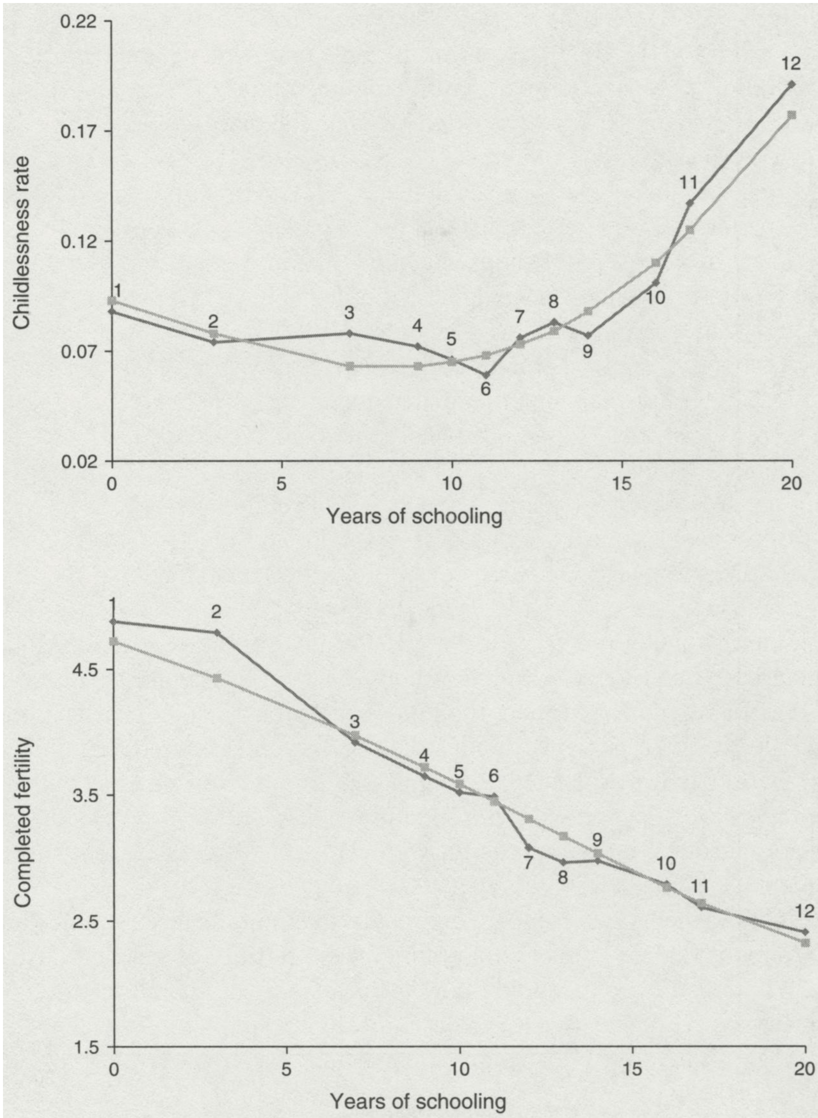

Figure 4. Childlessness Rate and Completed Fertility of Mothers, by Years of Schooling, Married Women

Note: Data (black), simulation (gray), education categories (labels).

mechanisms. Maximum fertility regimes, where poorly educated women would like to have more children but are constrained by their time endowment, concern 2.0 percent of American women (0.7 percent singles and 1.4 percent married). Women with the highest education are either childless [O] due to the high opportunity cost to childrear, or mothers in the unconstrained fertility case [U].

To dig deeper into the roots of childlessness when single, we have computed the fraction of single women in [O], whose marriage offer was rejected. This proportion

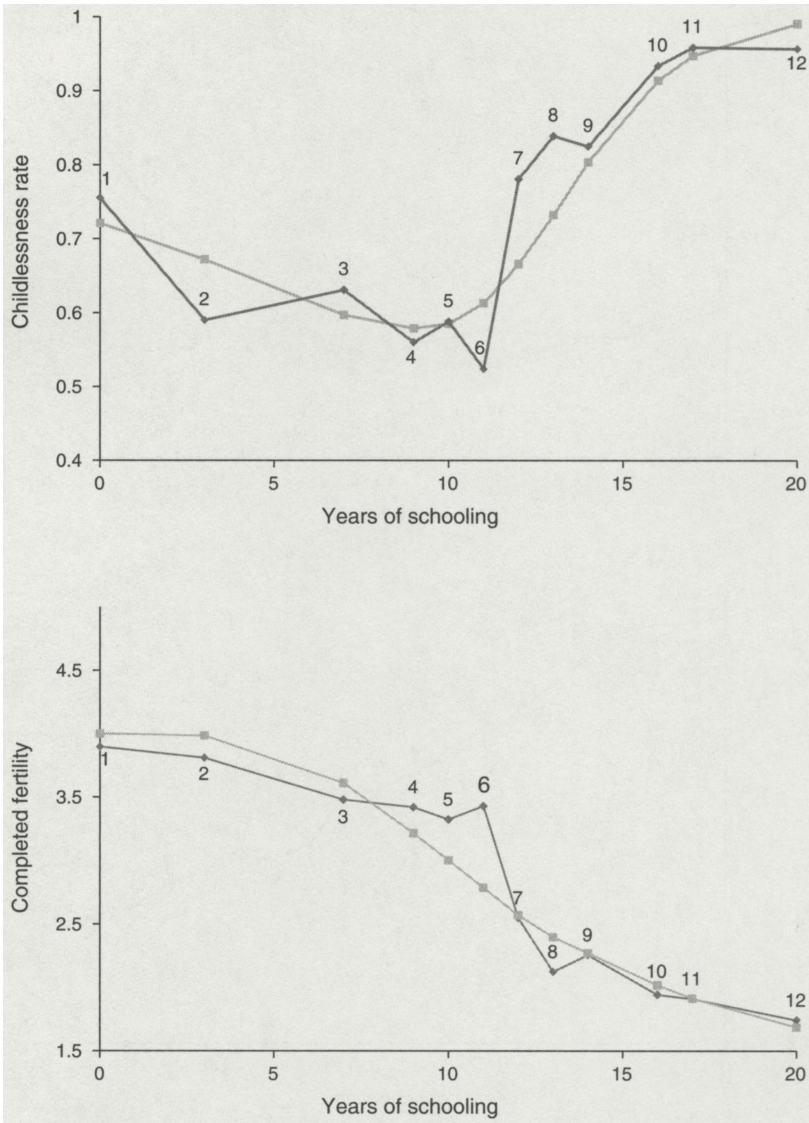

Figure 5. Childlessness Rate and Completed Fertility of Mothers, by Years of Schooling, Single Women

Note: Data (black), simulation (gray), education categories (labels).

is around 0.06 percent. Hence, the theory suggests that the majority of childless single women who are neither socially nor naturally sterile are single because they have rejected a marriage offer.

Figure 8 plots the percentage of women that are childless in each category of education, distinguishing whether it is driven by the opportunity cost of raising children, by poverty or by biological reasons. Considering all education categories, social sterility concerns 2.5 percent of American women (2.1 percent singles and

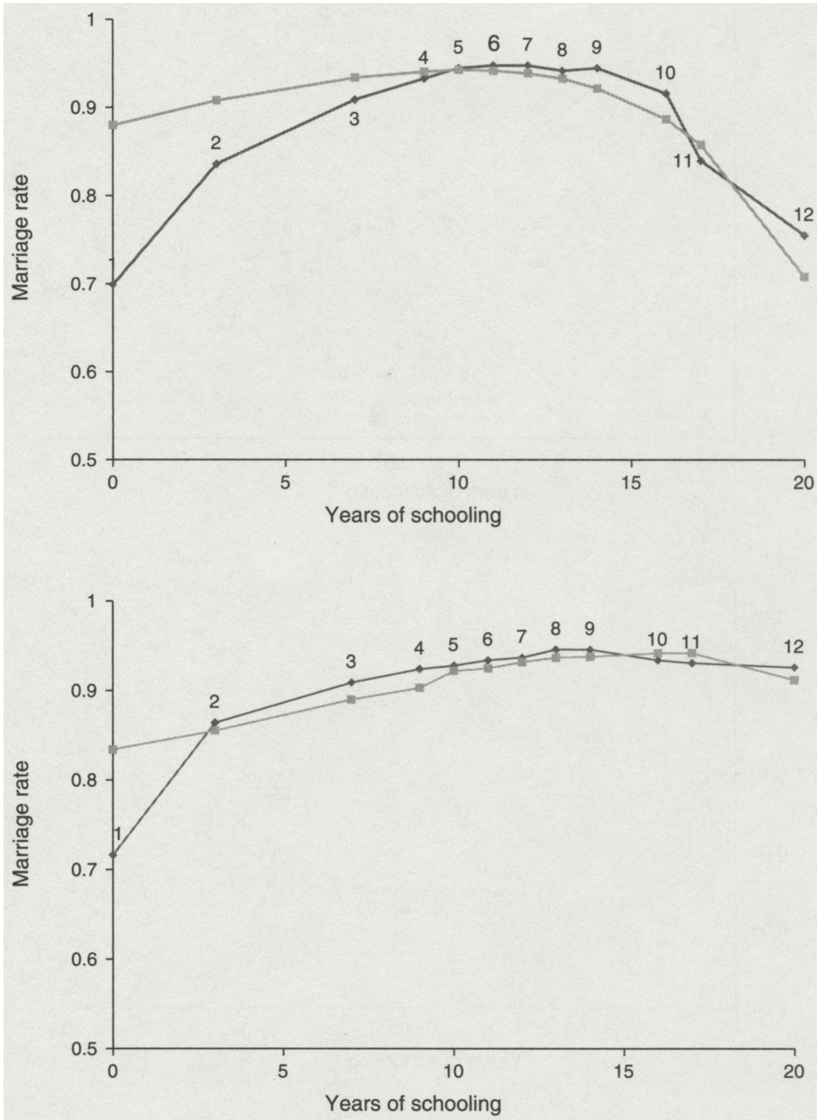

FIGURE 6. MARRIAGE RATES OF WOMEN (*Top panel*) AND MEN (*Bottom panel*), BY YEARS OF SCHOOLING

Note: Data (black), simulation (gray), education categories (labels).

0.4 percent married), while childlessness driven by a high opportunity cost concerns 8.1 percent of American women (3.3 percent singles and 4.8 percent married). Childlessness concerns essentially either lowly educated (socially sterile) or highly educated women, for both married and single people. The percentage of socially sterile women decreases with education, while the percentage of women who are childless because the opportunity cost of childrearing increases with education. This explains the U-shaped relationship between education and childlessness (Fact 2). The shape and location of this relationship depends mainly on three parameters.

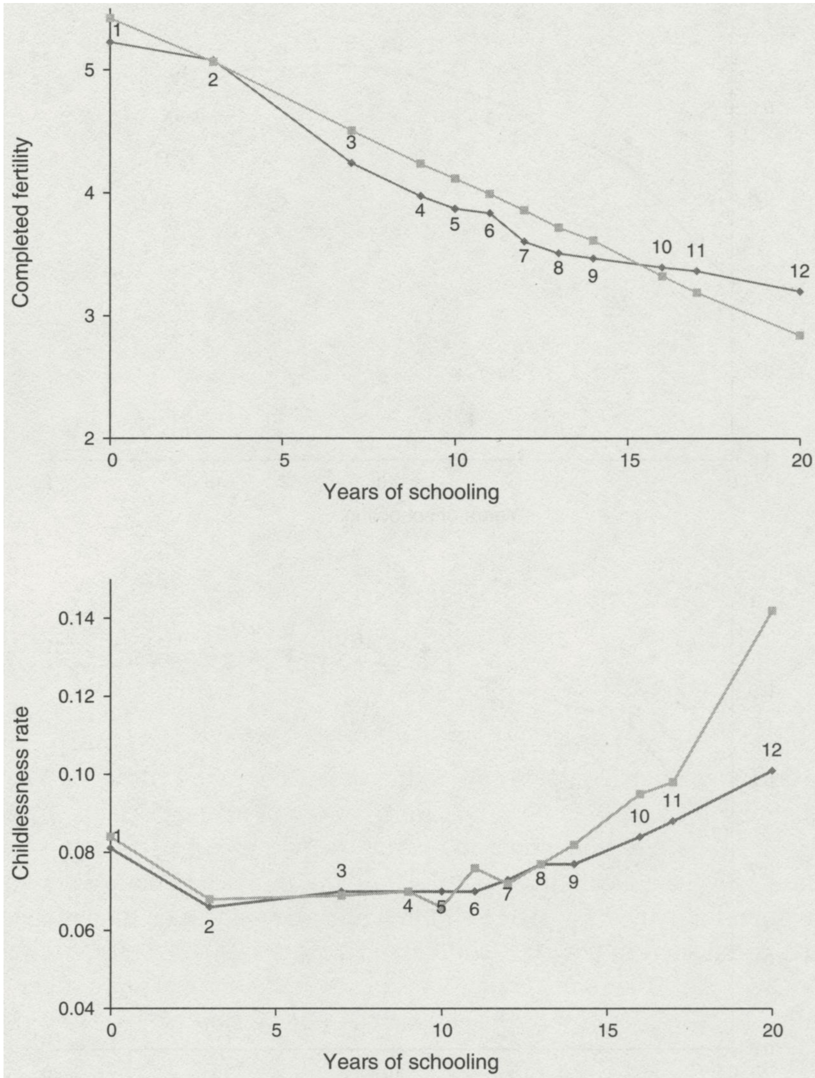

FIGURE 7. COMPLETED FERTILITY OF MARRIED FATHERS, CHILDLESSNESS RATES BY MARRIED MEN, BY YEARS OF SCHOOLING

Note: Data (black), simulation (gray), education categories (labels).

TABLE 4—DISTRIBUTION OF WOMEN BETWEEN ALTERNATIVE REGIMES

	Women's education			
Percent	1–2	3–9	10–12	Total
[N]	2.3	2.3	2.3	2.3
[S]	12.1	2.5	0.6	2.5
[M]	10.4	2.1	0.3	2.0
[C]	26.0	1.5	0.0	1.8
[O]	0.6	6.3	19.4	8.1
[U]	48.6	85.3	77.4	83.3

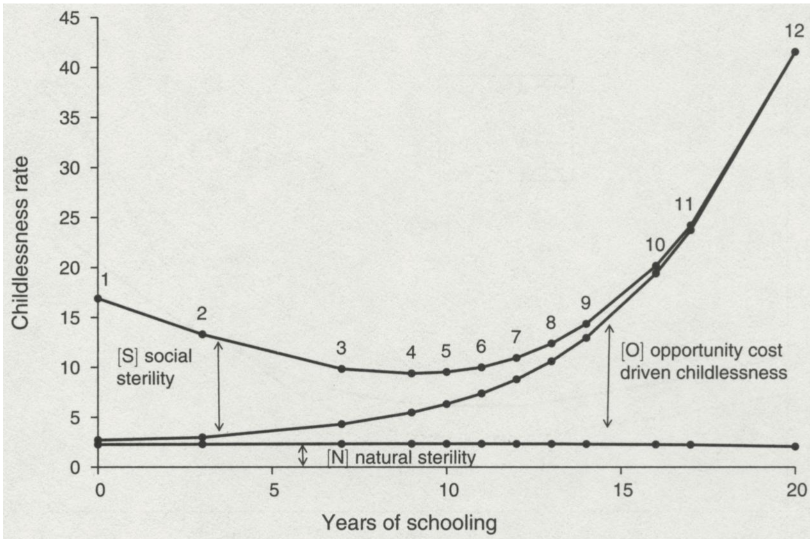

Figure 8. Childlessness Causes as Function of Women's Education

The top panel of Figure 9 shows that an increase in $\hat{c}$, holding the other parameters constant to their estimated values, makes the decreasing part of the U-shaped relationship steeper. A larger $\hat{c}$ implies that more women will remain socially sterile. A higher α mostly affects the increasing part of the U-shaped relationship between childlessness and the education of married women. In married couples, a larger α makes the opportunity cost of raising children more dependent on the wife's education, which is reflected in how fast childlessness increases as the wife's education increases. The fixed cost parameter η affects the overall extent of childlessness.

The hump shaped relationship between marriage and education is strongly related to the high childlessness rates of uneducated and highly educated single women as having children is the main motivation of men to marry in our setup. Especially marrying a woman who is very poor and requires help from the husband to procreate is less attractive than marrying better educated women. Another reason why highly educated women marry less is that they are more demanding in the type of marriage they accept as they do not have to rely on a husband to be protected against poverty. The three parameters that capture the economies of scale in marriage affect the shape of the relationship, as shown in the bottom panel of Figure 9. A higher δ^m incites men more to marry so they will accept more often a match with a low-educated women. On the contrary, a higher δ^f incites highly educated women more to marry. A higher μ makes everyone more willing to accept a match.

We have finally implemented several extensions of the model to test for robustness. First, in the benchmark model, we have included only one dimension of heterogeneity. Beyond non-labor income, preferences are the obvious candidate for another source of heterogeneity: some people might care more about having many children than others. We accordingly introduced one new parameter: the variance of the (lognormal) distribution of ν across individuals. Estimating this parameter

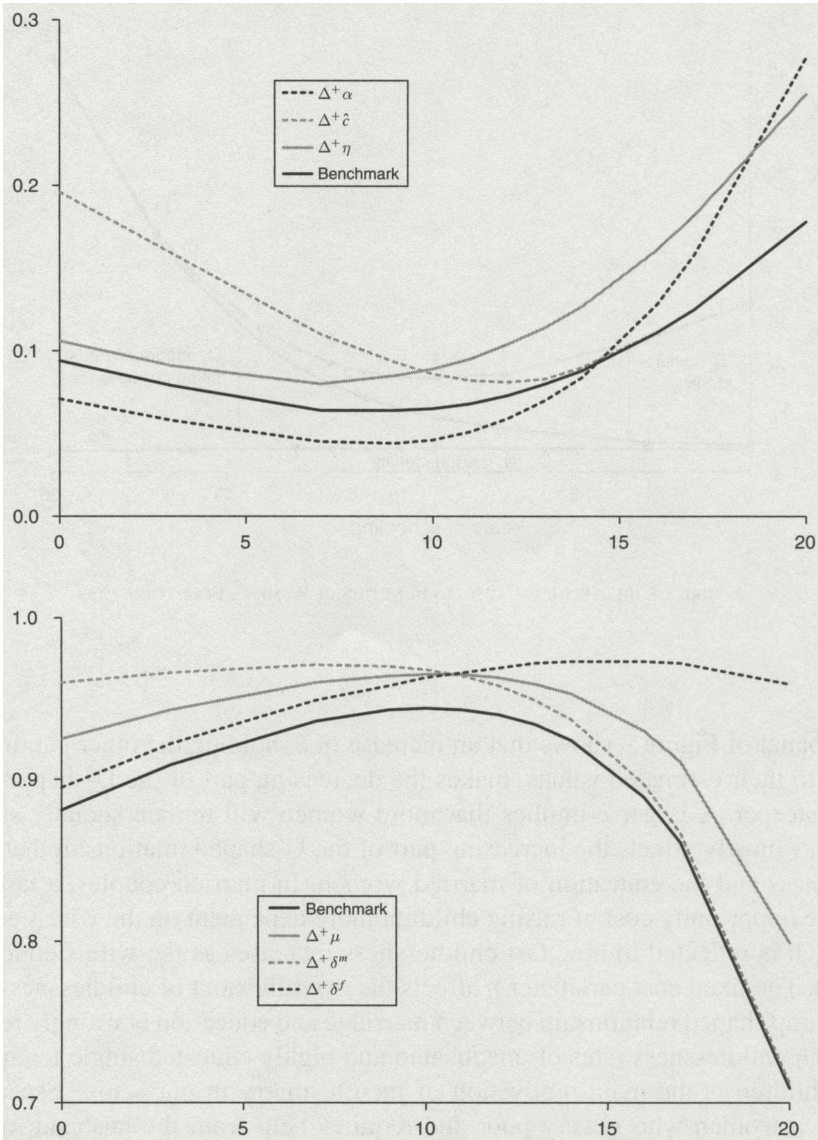

FIGURE 9. EFFECT OF SELECTED PARAMETERS OF THE CHILDLESSNESS OF MARRIED WOMEN (*Top*) AND ON THE MARRIAGE RATES OF WOMEN (*Bottom*)

together with the other parameters leads to the result that this variance should be zero. Introducing variability in ν increases variability of fertility when it is unconstrained, but this does not help to match the moments better. Hence heterogeneity in preferences on top of heterogeneity in non-labor income does not bring any advantage for our analysis. Second, the assumption that non-labor income is independent from education is relaxed in online Appendix C.3. Allowing for a nonzero correlation between education and non-labor income is not essential for the results. Third, despite having assumed random matching in the marriage market, the model predicts that individuals are more likely to marry someone with a similar level of education. This level of assortativeness is lower in the simulations than in the data because of the static nature of the model and the assumption that life only brings one chance to get married. In online Appendix C.8, we provide a way to measure the degree of assortativeness in the data and the model and discuss this question further.

IV. Counterfactual Experiments

Now, we use the parameters identified in Section III in several counterfactual experiments. The first is a historical experiment to understand the changes in childlessness and fertility for the cohorts born between 1871 and 1964. Then, we look at how an increase in inequality and a change in the wage gap affect childlessness and fertility.

A. *Historical Experiment*

We have already stressed in the introduction that childlessness and fertility are not always negatively correlated over time (top panel of Figure 1, for married women). Apart from the baby boom episode, the secular pattern of fertility is monotonically decreasing. Childlessness too, over the long-run, declined, from around 16 percent in the end of the nineteenth century to around 12 percent for the last cohorts for which completed fertility can be observed. All historical data are available in online Appendix A.8. In this section we use our theory to shed light on these long term trends.

In a cross-section of households, we have seen (Figure 8) that rising education leads to a decrease in childlessness for low levels of education and an increase in childlessness for high levels of education. The question we are investigating now is whether the same reasoning could be applied to explain the secular pattern of childlessness and fertility. To do so, we will rely on two mechanisms: the rise in education as observed in the different censuses, and an overall trend in income, related to the macroeconomic trend in total factor productivity.

Before turning to the results of the simulations, let us make clear that there are two features of the data that we have no hope to capture. The first is the baby boom, for the cohorts born between 1911 to 1940. The mechanisms that could generate the baby boom are absent from our framework.[25] The second particular feature of the data is the peak in childlessness for cohorts born between 1901 and 1915. In online Appendix A.8 we explain that this peak is related to a change in the census questionnaire. The Spanish Influenza and the Great Depression may also have played a role (see Sobotka, Skirbekk, and Philipov 2011).

To first address the effect of the increase in education, we keep wages fixed and scale them as to reproduce the average fertility of the generation born in 1941. We then simulate the model setting the shares of men and women in each education category to their historical values for each cohort, keeping everything else constant.

[25] Doepke, Hazan, and Maoz (forthcoming) suggest that part of the baby boom is caused by restrictions in the labor market for young women. Albanesi and Olivetti (forthcoming) also suggest that improvements in maternal health contributed to the bust. The raise in technological progress in the household sector is also one major cause of the baby boom, as shown in Greenwood, Shesardri, and Vandenbroucke (2005).

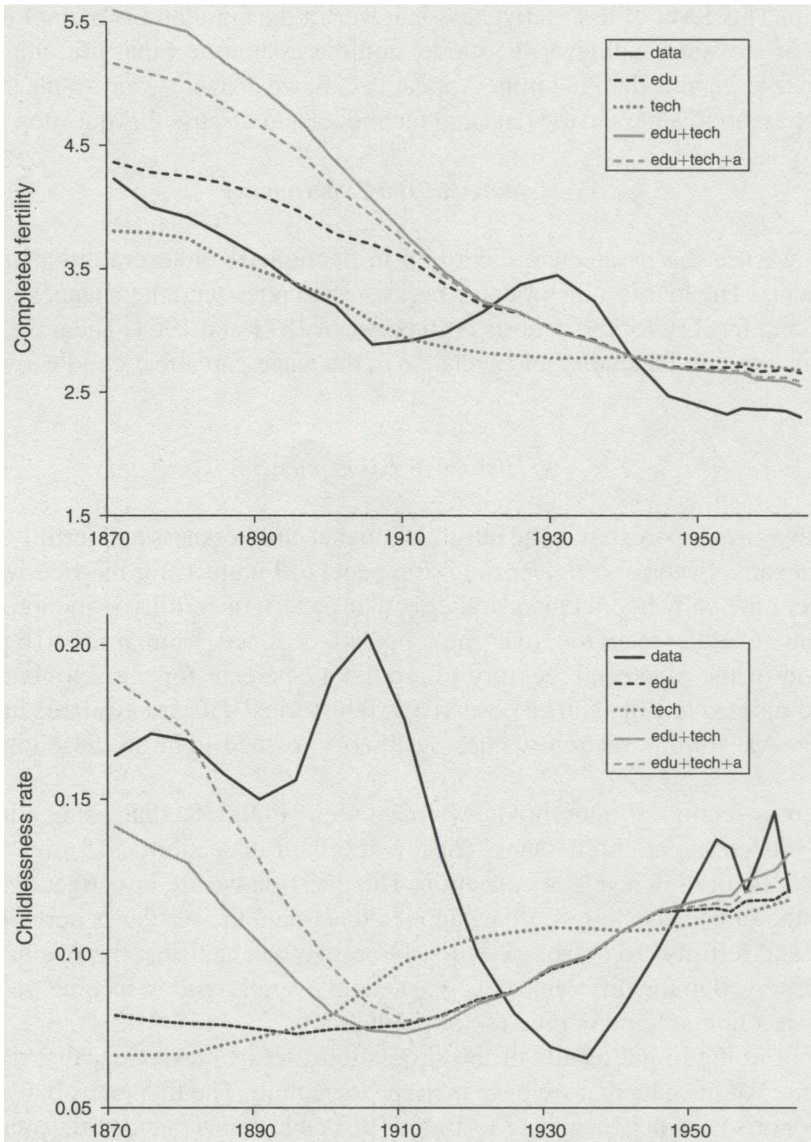

Figure 10. Completed Fertility of Mothers and Childlessness by Cohort, Married Only

The effects on completed fertility of mothers and childlessness are represented by the dashed lines of Figure 10. From the top panel, we observe that the rise in education leads to a monotonous decrease in fertility over time; alone it explains 87 percent of the drop in fertility (fertility drops from 4.23 to 2.30 in the data, and from 4.34 to 2.65 in the simulation). As for childlessness, the rise in education predicts a very slight U-shaped pattern for childlessness over time, according to the intuitions developed above. Most of the effect of education is still to increase childlessness due to the increase in the opportunity cost: indeed, in this counterfactual simulation, the wage is fixed at the level reproducing the fertility the 1941 cohort, which is quite high for nineteenth century standards, and this makes very few households affected by social sterility, even at the beginning of the period.

Secondly, we simulate the effect of a change in the overall wage level, following a trend in TFP (see online Appendix A.8.2 for its measurement). To isolate the effect of TFP, we keep education shares constant and equal to the levels of the cohort born in 1941. The dotted lines of Figure 10 show that the rise in TFP implies a monotonic decrease in fertility and a monotonic increase in childlessness.

We next combine the two sources of change in a single simulation. The total effect on fertility, represented by the gray line "edu+tech," is now too strong, which indicates that other exogenous elements may also have affected fertility. Interestingly, the effect on childlessness becomes strongly U-shaped over time. This is because the effect of the rise in education for the early cohorts is now evaluated at the wage relevant for each period. At the end of the nineteenth century, wages are low and many households are socially sterile. The rise in both education and TFP allow the subsequent generations to escape from that situation and childlessness first drops. Over time, the nature of childlessness changes, becoming more and more the optimal outcome of the fertility decision problem. Ultimately, education increases childlessness. This allows the simulation to capture the slight drop in childlessness over the very long run.

It is particularly interesting to notice that, in the simulation described above, the two driving forces, when taken alone, have either a monotonic increasing effect or a very slight U-shaped effect on childlessness. But once combined, their effect is to bring childlessness down through a nonmonotonic path. This highlights the interest of using a structural approach, which has the potential to generate interpretable non-linear effects.

Among the forces that are missing in the above analysis, there is one we can easily incorporate into the model: the fact that part of the non-labor income a is to be indexed on growth. As a includes bequests, gifts, welfare transfers, social security etc., it should in the long-run follow TFP developments. The gray line "edu+tech+a" gives the result of a simulation where, in addition to changes in wages and education shares, one third of a is indexed on TFP. In this simulation, households in the nineteenth century are less wealthy in terms of non-labor income than in the previous simulation where a was kept constant at the 1941 level. Hence, their fertility is reduced, and childlessness (social sterility) increased.

In sum, our theory suggests that the U-shaped relationship of childlessness rates over time is caused by a decrease in social sterility followed by an increase in childlessness due to a higher opportunity cost to raise children. Figure 11 confirms this interpretation, showing the breakdown of childlessness for married (top panel) and single (bottom panel) women separately. Social causes of childlessness have now completely disappeared for married women. This is however not true for singles for whom social sterility still exists.[26]

[26] Aaronson, Lange, and Mazumder (2014) use the variation of the extensive and intensive margins of fertility to assess the effect of a particular education policy in 1920. In doing so they assume that childlessness is a choice, i.e., it is driven by opportunity costs. This is however questionable, as their study concerns women born around or before 1900, for whom, according to Figure 11, childlessness is mostly related to poverty, and not driven by opportunity cost reasons.

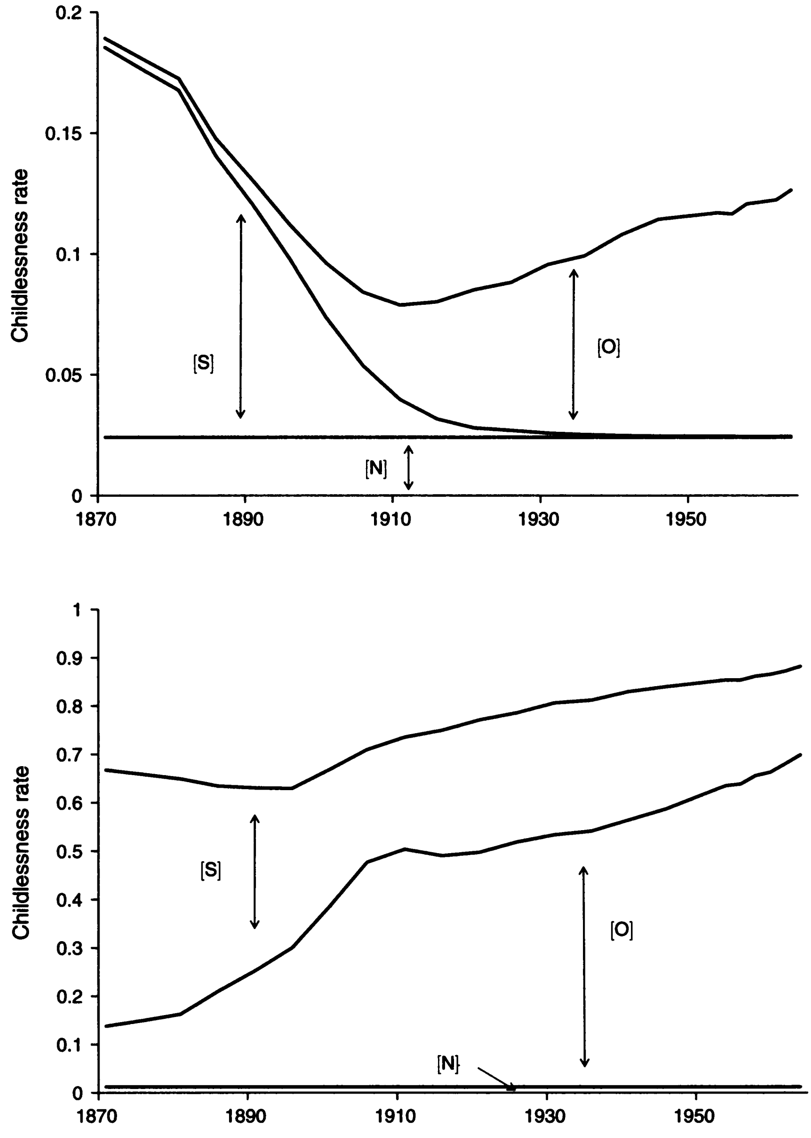

Figure 11. Detail of Simulated Childlessness by Cohort, Married (*Top*) and Singles (*Bottom*)

B. *Effect of Inequality* ρ *and Gender Wage Gap,* γ

Historically, there were also changes on the returns to schooling and on the gender wage gap (see online Appendix A.8). The effect of these changes on average childlessness and fertility are of second order compared to those of education and TFP. The reason is simply that changes in ρ and γ affect choices of the individuals that are in the tails of the distribution of education. As aggregate moments are mainly driven by the middle educated group, the effects of these two parameters are hidden.

Since 1980, income inequality and skill premia have been on the rise in the United States. To assess the effect on family patterns, we implement a rise in inequality through a change in the Mincer parameter ρ of equation (5). We increase the return of one additional year of education from 0.092 to 0.126 (see online Appendix A.8), keeping the wage of the largest category constant (Category 7); the change in the Mincer parameter thus increases the spread around the wage of high school graduates. This corresponds to an increase in the Gini coefficient computed on $w^f + a^f$ from 0.156 to 0.168.

As the lowly educated become poorer, the minimum consumption constraint binds more often and social sterility rises. For the highly educated, the opportunity cost of having children is increased by the higher skill premium (for both men and women), and more of them choose to remain childless. We then obtain a more pronounced U-shaped pattern for the higher Mincer coefficient (see top panel of Figure 12). On the whole, the proportion of socially sterile women [S] increases from 2.5 percent to 3.3 percent. This suggests that economic changes that make uneducated people better-off might have a positive effect on average fertility because they can affect the intensive margin and the extensive margin of fertility in opposite directions.[27]

Another first order change of the last decades is the closing of the gender wage gap (Goldin 1990 or Jones, Manuelli, and McGrattan 2015). To assess its effect on family patterns, we simulate the model for $\gamma = 0.755$, $\gamma = 0.869$, and $\gamma = 1$, keeping the other parameters fixed. $\gamma = 0.755$ is the lowest value provided in the historical estimates (online Appendix A.8). The bottom panel of Figure 12 shows the effect on childlessness for married women. As expected (Proposition 2 in online Appendix B.3), there will be fewer poor women in the social sterility regime, but educated women face a higher opportunity cost of raising children and are more likely to be childless.

V. Conclusion

The main contribution of the paper is to identify several causes behind childlessness that were not accounted for in previous studies of fertility. Childlessness can have natural, social, or economic causes. Social sterility appears for women with low education and low non-labor income, either single or married. A woman with an income that is not high enough to allow her to procreate can escape this situation if it is optimal for her husband to abandon part of his own consumption in order to enable her to produce children within the couple. This should be highlighted: although aggregate fertility data suggests that Malthusian checks do not prevail any more and Becker's model describes the relationship between education and fertility well, our model detects that some categories of the population are still affected by Malthusian mechanisms. For highly educated women, childlessness is driven by a high opportunity cost of childrearing.

Marriage interacts with childlessness in two ways; for poor women, marriage is an opportunity to get enough resources to be able to have children. Hence, marriage

[27] Such opposite effects are discussed in a historical case study by Romaniuk (1980) who shows that, during Zaire's modernization, fertility increased, partly due to a large reduction in childlessness rates between the 1930s and the 1960s.

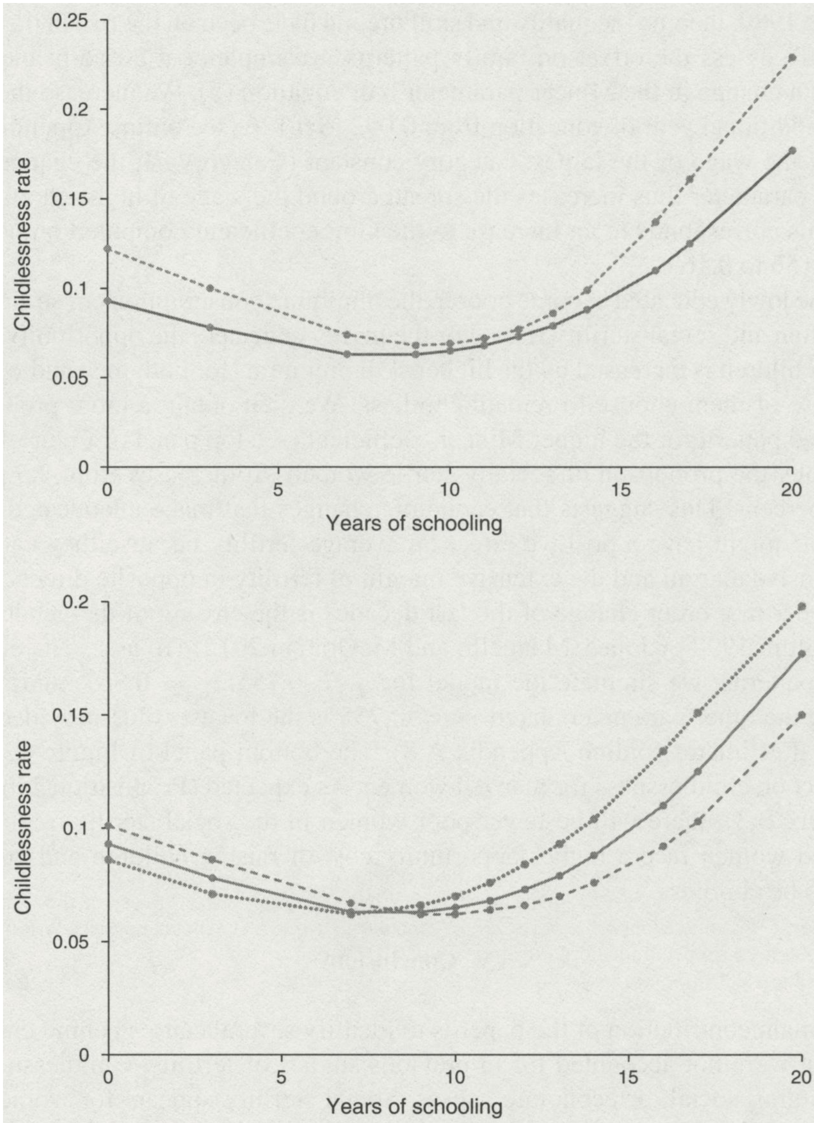

Figure 12. Childlessness Rate (*Married*)

Notes: Top panel: $\rho = 0.092$ (solid benchmark); $\rho = 0.126$ (dotted). Bottom panel: $\gamma = 0.755$ (dashed), $\gamma = 0.755$ (dashed), $\gamma = 0.869$ (solid), and $\gamma = 1$ (dotted).

reduces social sterility. For highly educated women, marriage reduces the opportunity cost of having children, as husbands also help with raising the children. It therefore also reduces childlessness at the high end of the female education distribution. The causality also goes from childlessness to marriage in the sense that because they are more prone to be childless, women at both tails of the education distribution have more difficulties to marry.

Looking at the data without a structural model does not allow us to distinguish both types of childlessness, and evaluate their relative importance in a given society.

Our structural approach allows to infer from the behavior of the agents the unobserved components of childlessness. Hence the importance of combining theory with data in order to measure the share of childlessness that is related to poverty and/or inequalities. Our analysis suggests that closing the gender wage gap is a powerful tool for limiting the proportion of childlessness that is generated by poverty.

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