working paper
1912

The Wife's Protector: A Quantitative Theory Linking Contraceptive Technology with the Decline in Marriage

Jeremy Greenwood
Nezih Guner
Karen A. Kopecky

December 2019

CENTRO DE ESTUDIOS
MONETARIOS Y FINANCIEROS
Casado del Alisal 5, 28014 Madrid, Spain
www.cemfi.es

CEMFI Working Paper No. 1912
December 2019

The Wife's Protector: A Quantitative Theory Linking Contraceptive Technology with the Decline in Marriage

Abstract

The 19th and 20th centuries saw a transformation in contraceptive technologies and their take up. This led to a sexual revolution, which witnessed a rise in premarital sex and out-of-wedlock births, and a decline in marriage. The impact of contraception on married and single life is analyzed here both theoretically and quantitatively. The analysis is conducted using a model where people search for partners. Upon ?nding one, they can choose between abstinence, marriage, and a premarital sexual relationship. The model is confronted with some stylized facts about premarital sex and marriage over the course of the 20th century. Some economic history is also presented.

JEL Codes:

Keywords: Age of marriage, contraceptive technology, history, never-married population, number of partners, out-of-wedlock births, premarital sex, singles.

Jeremy Greenwood
University of Pennsylvania

Nezih Guner
CEMFI
nezih.guner@cemfi.es

Karen A. Kopecky
FRB Atlanta
karen.kopecky@atl.frb.org

Acknowledgement

In preparation for Bisin, Alberto and Giovanni Federico, Eds. (2020, Expected) Handbook of Historical Economics. Elsevier North Holland, Amsterdam. Dedicated to Stanley L. Engerman, one of the great economic historians. The authors thank Jordan Herring and Yueyuan Ma for research assistance. The title refers to John B. Beers' 1846 Wife's Protector contraceptive device.

1 Introduction

The forward motion of technology is unrelenting. It's hard to think of anything else that has affected the economy and society in such a fundamental way. The Second Industrial Revolution occurred as the clock chimed in the 20th century. It ushered in electricity, the petrochemical industry, and the internal combustion engine. It's ramifications were enormous. Electricity and the internal combustion engine changed the workplace since many manual tasks could now be mechanized. This combined with fertilizers reduced the need for farm labor. Along with the automobile it encouraged the rise of cities and suburbs. Electricity also meant that the home could be mechanized. The mechanization of the home and industry allowed women to enter the labor force. This provided a catalyst for bestowing women's rights in the workplace.[1]

The Information Age (or the Third Industrial Revolution) is also transforming the economy and society. The ENIAC, the first general purpose computer, was set to work at the University of Pennsylvania in 1945. Machines like this were first used in academic and industrial research to perform calculations that were impractical or impossible to do manually. By the 1960s it was apparent that computers could be used to sort, store, process, and retrieve large volumes of data. Networking and the personal computers came online in the 1970s and the 1980s. All of this reduced the need for labor on factory floors, by using numerically controlled machines and flexible manufacturing, and eliminated the need for battalions of clerks, pools of secretaries, scores of purchasing and sales agents, and layers of supervisors and administrators. The recent rise of artificial intelligence is reducing the need for routine mental labor.

Seemingly small inventions can also have a huge impact on the economy and society. Take, for instance, the discovery of penicillin in 1928 by Sir Alexander Fleming, which was the dawning of the antibiotic era. The leading causes of death in the United States changed from infectious illnesses (cholera, diphtheria, pneumonia, smallpox, typhoid fever, plaque, syphilis, tuberculosis, typhus) to noninfectious ones (cardiovascular disease, cancer, and stroke). At the beginning of the 20th century life expectancy was 47 years compared with 79 years today. Better health and longer lives have

[1] The impact of technology on family life is the subject of the prescient book by Ogburn and Nimkoff (1955) and more recently by Greenwood (2018).

affected educational attainment, labor-force participation, retirement, and savings. Contraception is another small invention with profound implications.

Technological innovations such as these can be analyzed using quantitative theory. Quantitative-theoretic history aims to develop economic models of historical issues. The models generally start at the level of profit maximization by firms and/or utility maximization by individuals and then aggregate up to get a description of the economy as a whole. There are several key ingredients in such an approach. First, is posing an interesting historical question. Second, is providing an historical narrative for the question's background. Third, is the development of an economic model to address the question. Fourth, is analyzing the model to glean intuition about its mechanics and establish any theoretical propositions. Fifth, is simulating the model to see if it can delivery a viable explanation of the historical data surrounding the question of interest. The analysis may end there but often counterfactual experiments are entertained. Hence, quantitative theory can take data and ideas from economic history and address them using the tool kit of modern macroeconomics. The question to be addressed here is: How did technological progress in contraception influence the decline in marriage over the course of the 20th century? The analysis will follow the above five steps.

1.1 Quantitative-Theoretic History: Some Examples

Early examples of using quantitative theory to address historical questions are the works by Cooley and Ohanian (1997), Greenwood and Yorukoglu (1997), and Ohanian (1997). Cooley and Ohanian (1997) and Ohanian (1997) study whether it would have been better to finance World War II by debt or taxation. Their finding is that raising taxation in war times, as Keynes suggested, is a bad idea. Greenwood and Yorukoglu (1997) study three industrial revolutions and find that they are characterized by plunging prices for new technologies, productivity slowdowns, and rising income inequality. They model this phenomena.

Some more recent examples are Cole and Ohanian (2004), Greenwood, Seshadri, and Vandenbroucke (2005), Hansen and Prescott (2002), Kopecky (2011), Kopecky and Suen (2010), and Vandenbrouke (2008). Cole and Ohanian (2004) argue that Roosevelt's New Deal policies, by strengthening the power of monopolies and unions, prolonged the Great Depression.

This is in stark contrast with the conventional fawning view of the New Deal. The secular decline in U.S. fertility from 1800, which was briefly interrupted by the baby boom, is addressed in Greenwood, Seshadri, and Vandenbroucke (2005). The transition from the preindustrial to the industrial era is modeled by Hansen and Prescott (2002), who emphasize the switch from land-intensive to capital-intensive production technologies. Caucutt, Cooley, and Guner (2013) built on Hansen and Prescott (2002) to study the emergence of the social security system along this transition. In 1880 more than 75 percent of 65-year-old males were still working, compared with only 20 percent in 2000. Kopecky (2005) analyzes the rise in retirement over the course of the 20th century. Kopecky and Suen (2010) develop a model of a city with two modes of transportation, namely buses and cars, and address the impact of the automobile on suburbanization between 1910 and 1970. The expansion of the American West is addressed in Vandenbrouke (2008), using a model that incorporates endogenous fertility and migration. Last, some of the literature on marriage discussed in Section 10 also falls within the category of quantitative-theoretic history; viz., Albanesi and Olivetti (2016), Fernandez-Villaverde, Greenwood, and Guner (2014), Greenwood and Guner (2009, 2010), Greenwood, Seshadri, and Yorukoglu (2005), Knowles and Vandenbroucke (2019), and Vandenbroucke (2014).

2 The Decline in Marriage

> Since the best way to learn about someone else is by being together, intensive search is more effective when unwed couples spend considerable time together, perhaps including trial marriages. Yet when contraceptives are crude and unreliable, trial marriages and other premarital contact greatly raise the risk of pregnancy. The significant increase during this century in the frequency of trial marriages and other premarital contact has been in part a rational response to major improvements in contraceptive techniques, and is not decisive evidence that young people now value sexual experiences more than they did in the past. Gary S. Becker (1991, p. 326)

Since World War II there has been a dramatic increase in the fraction of young women who have never been married and consequently an associated

Figure 1: Marriage in the United States, 1880-2015/8. The figure plots the fraction of the female population, ages 18-30, that are never married and the median age of first marriage for women. See the Data Appendix for all data sources.

rise in the age of first marriage. These two trends are shown in Figure 1. (All data sources are provided in the Data Appendix.) In 1900 only 48 percent of women in the 18 to 30 age range had never been married. By 2015 this had jumped to 77 percent. The median age of a first marriage rose from 21 to 25. The hypothesis to be entertained here is that this is due, at least in part, to technological improvements in contraception. As the failure rate for contraception fell, the cost of a sexual relationship for a single woman also declined. This altered the cost/benefit calculation for marrying a partner at hand, favoring the option of postponing marriage until a more suitable partner is found.

Somewhat paradoxically as contraception improved, the number of non-marital births rose. Over the course of the 20th century non-marital births rose continuously, as is displayed by the right panel of Figure 2. This occurred for two reasons: the fraction of never-married women has increased (Figure 1 above) and never-married women are more sexually active today than in the past (which is discussed below). The left panel shows that non-marital births have increased throughout the postwar period for every age group of women. Additionally, the non-marital births for women in the adult age groups now

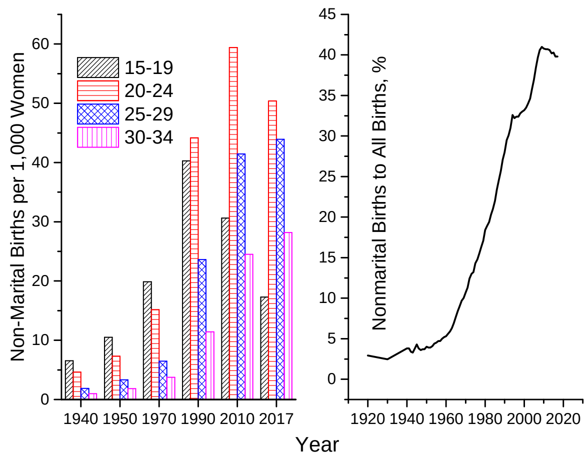

Figure 2: Non-Marital Births in the United States. The right panel shows non-marital births as a percentage of all births, 1920-2017. The left panel displays non-marital births by age group per 1,000 women at various times in the postwar period.

exceed that for teenagers.

Never-married women are much more sexually active today than in yesterday. The percentage of 20-year-old women experiencing premarital sex rose precipitously over the course of the 20th century. Only 8 percent of women born around 1900 would have had premarital sex before age 20, compared with 76 percent born between 1978 and 88–see Figure 3. Furthermore, the circa 1900 cohort of women would have had around sexual 2.8 partner before marriage, including her husband, while the 1978-88 cohort had 7.0 partners.

A marital search model is used to examine the impact on marriage of technological innovation in contraception. The model is setup in Section 4. In particular, each period a single searches for a partner on a marriage market. If the person is matched, they can choose to have a casual relationship with the partner or enter into marriage. There are two types of casual relationships; viz., sexual and nonsexual ones. A nonmarital sexual love affair involves the risk of pregnancy, which depends on the effectiveness of contraception.

When choosing between a casual relationship and marriage a person examines the marriageability of their partner versus the momentary utility from

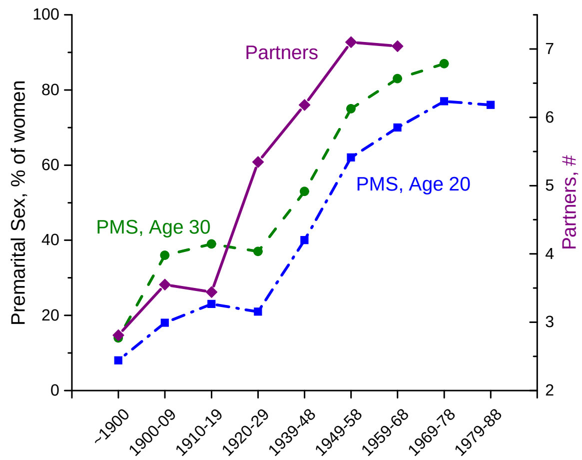

Figure 3: Premarital Sex in 20th-Century America. The graph plots the percentage of women, by various cohorts, who had premarital sex by ages 20 and 30, left axis. It also charts the number of partners these women had before marriage, right axis.

a nonmarital romance and then continuing the search for a more marriageable mate. This choice is presented in Section 5. To keep things simple, the analysis abstracts from divorce. Likewise, when deciding between an abstinent or a sexual relationship the individual weighs off the extra utility from having sex against the expected cost of an out-of-wedlock birth. This decision is formalized in Section 6. It is established theoretically that an improvement in contraceptive technology leads to: a decline in the rate of marriage (Section 5); an increase in the fraction of the population that are never-married (Section 7.1); a postponement in the age of marriage (Section 7.1); and a rise in the fraction of singles that are sexual active (Section 7.2). Out-of-wedlock births may rise or fall with an advance in contraceptive technology (Section 7.4).

The theoretical model is subjected to some quantitative analysis in Section 8. To begin with, a series measuring the failure rate of contraception is constructed. The odds of a pregnancy for a sexually active women dropped precipitously between 1900 and 2015-18. The analysis focuses on two periods in U.S. history, 1900 and 2000. The model is calibrated to see if it can match facts from the U.S. data such as the decline in the fraction of women who have ever been married, the fraction of single women who had premarital sex, the increase in out-of-wedlock births, and the waxing in the number of sexual partners before marriage. The developed framework matches these facts well. The mapping between data targets and parameter values is unpacked by computing the Jacobian for the model.

Last, a review of the relevant economics literature on the decline in marriage is presented in Section 10. The discussion now turns to a brief history of contraception.

3 Contraception in the 19th and 20th Centuries

Birth control advanced along two fronts in the nineteenth century. First, knowledge about contraception began to disseminate. Second, there was improvement in contraceptive technologies. Historically, fertility for married women was controlled in the United States, albeit very imperfectly, using primitive contraception. These technologies would have been too risky to use for unmarried women.

Using a reproductive period of 25 years and an interval between births of 1.5 years, Livi-Bacci (2012) estimates that a reasonable upper bound on the number of children that a woman can have is 16.7. No society has approached this theoretical maximal rate of reproduction. The closest examples are the 17th century Québécois and the interwar Canadian Hutterites with total fertility rates of 11.4 and 9, respectively.[2] The total fertility rate for white women in the United States fell from 7.1 children in 1800 to just 1.9 kids in 2015, as can be seen from the right panel of Figure 4. The figure also plots the complementary cumulative distribution functions over births for four cohorts of married women in the United States before the baby boom–see the left panel. First, as can be seen, the distribution of births is well within the biological maximum. Second, the distribution functions are stochastically decreasing with the year of the cohort. That is, as time progresses a woman was less likely to have a large number of births. For example, the first group of bars shows that 15 percent of woman born between 1835 and 1839 had 10 or more births. This had dropped to just 1.7 percent for the 1905-

[2] Galor and Klemp (2019), in their study of the fecundity of early French Canadian women, relay that one woman had 22 offspring.

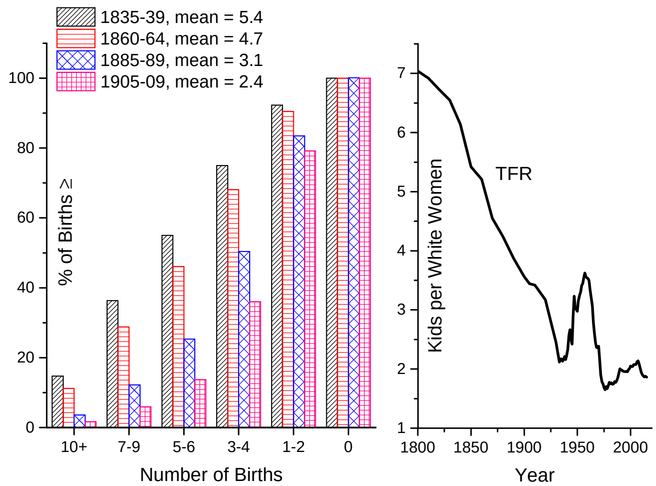

Figure 4: Fertility in the United States. The right panel shows the drop in the total fertility rate for white women from 1800 to 2015. Complementary cumulative distribution functions over children ever born for four cohorts of ever-married women are plotted in the left panel. As such, the vertical axis presents the percentage of women who had a number of births greater than or equal to that indicated on the horizontal axis.

09 cohort. At the other end of the spectrum, it can be deduced from the difference in the heights between the fifth and sixth groups of bars that just 7.7 percent of women in the 1835-39 had no children, while 21 percent did for those born between 1905 and 1909. The mean number of births declines with the women's birth years. The mean of 2.5 for the 1905-09 cohort compares with a total fertility rate of 1.9 in 2015. The 1905-09 cohort would have been in their fifties by the time the pill was invented. So, the graph clearly illustrates that somehow family size was limited well before the advent of modern contraception. Historically, family size was limited by abortion, abstinence enforced by the prohibition and stigmatization of premarital sex, contraception, child abandonment and infanticide, and delaying the age of marriage (which was important in light of short lifespans).

3.1 Dissemination of Information

In 1823 Francis Place, an English social reformer, circulated a pamphlet in London titled *To the Married of Both Sexes of the Working People.* In it he wrote [Himes (1963, pp. 216-217)]

> "What is done by other people is this. A piece of soft sponge is tied by a bobbin or penny ribbon, and inserted just before the sexual intercourse takes place, and is withdrawn again as soon as it has taken place. Many tie a piece of sponge to each end of the ribbon, and they take care not to use the same sponge again until it has been washed."

An early nineteenth century sponge is shown in the right panel of Figure 5.

In America, Dr. Charles Knowlton (1832) recommended douching in a pamphlet titled *The Fruits of Philosophy* (Chapter III on "Promoting and Checking Conception"), writing

> "It consists in syringing the vagina immediately after connection with a solution of sulphate of zinc, of alum, pearl-ash, or any salt that acts chemically on the semen, and at the same time produces no unfavorable effect on the female."

The first edition was published anonymously, given the puritanical beliefs of the time. For trying to distribute his book, Knowlton was imprisoned for three months. Figure 5, left panel, shows an early vaginal syringe used for douching. Last in *Moral Physiology; or, A Brief and Plain Treatise on the Population Question* (Chapter VI) Robert Dale Owen (1842) advocated withdrawal, stating

> "Among the modes of preventing conception which may have prevailed in various countries, that which has been adopted, and is now practised by the cultivated classes on the continent of Europe, by the French, the Italians, and, I believe, by the Germans and Spaniards, consists of complete withdrawal, on the part of the man, immediately previous to emission. *This is, in all cases, effectual.*"

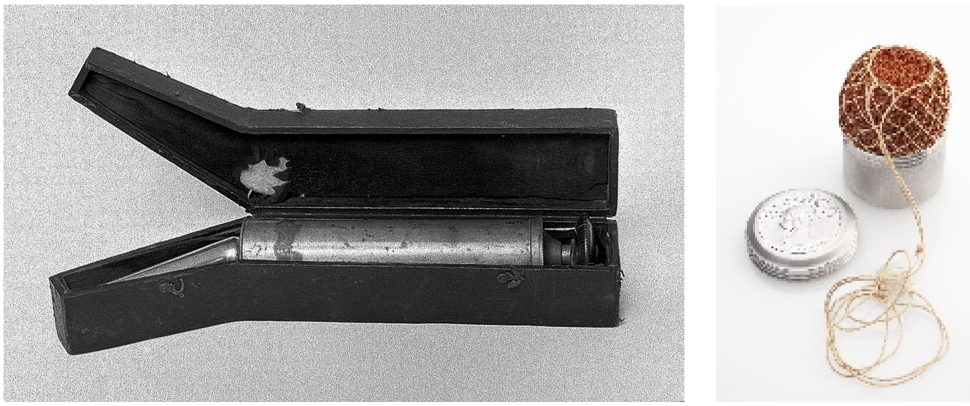

Figure 5: A 19th century pewter vaginal syringe with its case is displayed in the left panel. The right panel shows a rubber sponge, in its original box (circa 1901-1930). Sponges were widely used as contraception in the early 1900s. Sponges were often soaked in spermicidal agents, of varying effectiveness. In a 1914 pamphlet *Family Limitation*, Margaret Sanger relayed that absorbing boric acid into the sponge yielded "satisfactory results." *Sources*: wellcomecollection.org and Science Museum, London.

The dissemination of knowledge about birth control picked up dramatically at the start of the twentieth century. In 1916 Margaret Sanger opened the first birth control clinic in America. Some 400 women received instruction about contraception before the clinic was closed by the police nine days later. Sanger served a thirty day jail sentence in 1917 for opening the clinic. Following a 1918 ruling by the New York State Court of Appeals in *The People of the State of New York v. Margaret H. Sanger*, which allowed contraception to be distributed by physicians, she opened the first continuously operational birth control clinic in 1923. The clinic was staffed by female physicians and counselors. In London, England, Mary Stopes did much the same thing, opening in 1921 the first birth control clinic in the British Empire. The first medical book in America aimed at providing physicians with up-to-date scientific information about contraception was the *Technique of Contraception: The Principle and Practice of Anti-Conceptional Methods*, written by Dr. James F. Cooper in 1928. A table in the book (p. 221) gave failures rates for condoms, douching, cervical stems, spermicides, withdrawal, etc. The book was dedicated to Margaret Sanger.

3.2 Technological Advance

There also was considerable technological advance in contraception over this period. Start with the condom. In 1844 *The United States Practical Receipt Book* (p. 87) provided instructions on how to make a condom:

> "Take the caecum of the sheep; soak it first in water, turn it on both sides, then repeat the operation in a weak ley of soda, which must be changed every four or five hours for five or six successive times; then remove the mucus membrane with the nail; sulphur, wash in clean water, and then in soap and water; rinse, inflate, and dry. Next cut it to the required length and attach a piece of ribbon to the open end. Used to prevent infection or pregnancy. The different qualities consist of extra pains being taken in the above process, and in polishing, scenting, &c."

Packages of a dozen rubber condoms were selling in 1890 for 50 cents. At the time a tradesman would have earned an hourly wage of 20 cents, so this translates into a time price of 2.5 hours of work. Quality control was an issue; however, giving condoms a bad name. According to Tietze (1963), a study conducted in 1934-1935 found the following distribution over defects: burst, 29.4 per cent; holes, 15.2 per cent; flaws, 14.5 per cent; total, 59.1 per cent. This led to the U.S. Food and Drug Administration controlling quality standards. Also, Dr. Cooper in his 1928 medical book noted another disadvantage: "Blunting of sensation. Frequent refusal by male." The quality of condoms had increased dramatically by the 1960s, making them one of the most effective forms of contraception.

In 1846 the United States Patent Office granted patent number 4,729. The introduction to the patent specification read:

> "Be it known that I, John B. Beers, of the city of Rochester, in the county of Monroe and State of New York, have invented a new Instrument called the 'wife's protector,' the design of which is to Prevent conception."

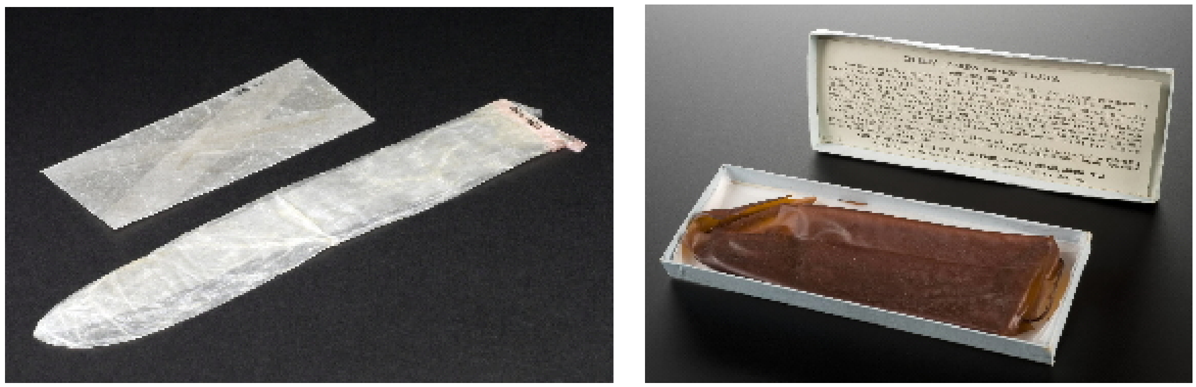

Figure 6: The left panel shows a European condom, made from animal gut, in a waxed paper envelope (circa 1801-1850). The right panel pictures a reusable English rubber condom in its original box, complete with instructions (circa 1948). *Source*: Science Museum, London.

The drawing that was submitted with his patent application is shown in Figure 7. The specification of Beers' letters patent is provided in Appendix 11. His wife's protector instrument inserted a hoop covered by a oil-silk membrane that prevented semen from entering the uterus. An interesting feature of the patent specification is that is explicitly stated that it was intended to prevent pregnancy, a risky venture at the time. Cervical caps and diaphragms also were introduced in the 1800s. The left panel of Figure 8 shows a late 18th century German pessary. The pessary was an intracervical device (IUC). It worked after conception by provoking a foreign inflammatory reaction that stops a newly fertilized embryo from implanting and growing in the lining of the uterus.

There was also technological improvement in spermicides, used with or without other contraceptives such as condoms, diaphragms, sponges, etc. An English pharmacist introduced in 1885 a suppository made out of cocoa butter and quinine sulfate. Others at the time combined cocoa butter, which melted at a low temperature, with boric acid, tannic acid, or bichloride of mercury. In 1937 phenylmercuric acetate was introduced in a product called Volper. This was a highly effective spermicide, but was subsequently banned in the United States because of concerns about mercury. In the 1950s surface active agents (surfactants) were introduced. These are non-irritating. On this, in the past many products were used as spermicides. Sanger (1914)

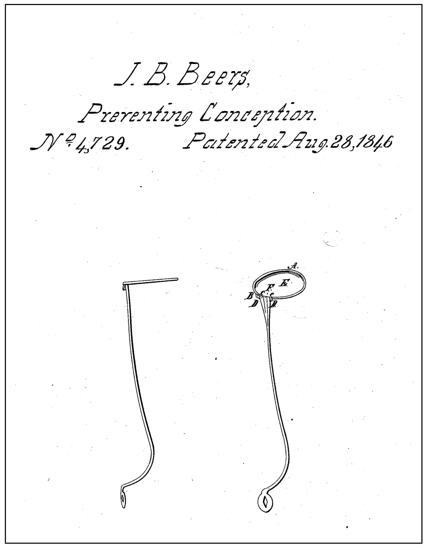

Figure 7: The drawing that was submitted with John B. Beers' 1846 patent application for his Wife's Protector contraceptive device.

mentions Lysol in *Family Limitation* and Belsky (1975) relays that Coca-Cola was used in India.

In the 1920s German gynecologist Ernst Grafenberg developed the intrauterine device (IUD), displayed in the right panel of Figure 8. Both the pessary and this early IUD were infection prone. And it should be noted that pelvic infections could only be dealt with easily after the introduction of antibiotics in the 1940s. Fast forwarding to 1967, Howard Tatum and Jamie Zipper developed the first copper-bearing IUD. It was T shaped and made of inert plastics, which made it fit better and less vulnerable to infection. Zipper had shown that copper reduced the risk of pregnancy in rabbits. Interestingly, Grafenberg's IUD also contained copper, but its effect on preventing pregnancy went unnoticed.

Also in the 1920s and 1930s two gynecologists, Kyusaku Ogino and Hermann Knaus, provided an accurate tracking of the ovulation cycle. This provide a scientific basis for the rhythm method. This resulted in inexpensive devices, such as the Rythmeter, which calculated the time of ovulation and the periods of fertility and infertility. This evolved into more modern methods, such as Sympto-Thermal Method of the late 1970s, which combines the rhythm calendar with changes in body temperature and cervical mucus.

Figure 8: A gold wishbone stem pessary is pictured in the left panel. It was developed around 1880 in Germany. The right side panel shows a Grafenberg IUD, circa 1920s. *Source*: Science Museum, London.

The pill symbolizes technological improvement in contraception. It synthesizes two hormones, estrogen and progestin, in order to prevent ovulation. Scientists discovered and isolated hormones in the 1930s. Manufacturing them was expensive and slow, though. Russell Marker developed an efficient method for doing so in the 1950s. Around that time Carl Djerassi synthesized a progestin that could be taken orally. Capitalizing on these earlier breakthroughs, biologists Min Chueh Chang and Gregory Pincus teamed together with obstetrician John Rock to develop the pill, which was approved by the FDA in 1960. Today transdermal patches, implants, and injections can be used to deliver estrogen and progestin.

4 Setup

Each period a new cohort of adult singles enters the economy. The initial size of each cohort is one, with a per-period survival rate for a person of σ. The analysis will focus on the steady states. Given this, the time-invariant size of the population is $1/(1-\sigma)$.

Now, imagine the problem facing a single. Suppose that this single will meet a partner in the current period with probability μ. If so, the person can decide to have either a marital or nonmarital relationship with their partner.

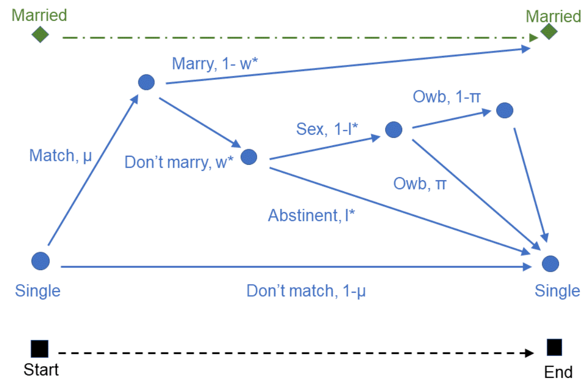

Figure 9: Timing of Events. The diagram shows the timing of events within a period. The circles denote nodes when an individual is single, whereas the diamonds represent nodes when they are married. A single matches with probability μ. If matched, they remain single with probability w^*, have sex with odds $1 - l^*$, and have an out-of-wedlock birth (owb) with probability, $1 - \pi$. The determination of w^* and l^* is discussed in the next two sections.

There are two types of nonmarital love affairs: sexual and nonsexual ones. An abstinent romantic entanglement yields a momentary utility level of $a \geq 0$. A sexual liaison results in a current utility level of $l > a$. Libido, l, for the current love affair is drawn from the cumulative distribution function $L(l)$, with associated density function $L_1(l)$. A nonmarital sexual relationship may result in an out-of-wedlock birth. With probability π the person avoids a pregnancy, while with probability $1 - \pi$ they do not. Let an out-of-wedlock birth have a cost of O. Finally, if the person marries, then they get the random lifetime utility w. The value of being wed, $w \geq 0$, is drawn from the cumulative distribution function $W(w)$, with associated density function $W_1(w)$. The value of w is known at the time of the marriage decision, but the level of joy, l, from a casual sexual endeavour is not. Marriage is an absorbing state. People discount the future at rate β, which incorporates the survival rate of σ.

5 Married or Single Life?

The key step in the analysis is formulating the recursion that defines the expected lifetime utility of being single in the current period, S. Suppose that the person is single in the current period. With probability $1-\mu$ the person remains unmatched. In this case, they realize no current utility. Since they enter next period as unmarried, the discounted expected utility for an unmatched single is βS. With probability μ they meet someone. If so, the single can choose to marry or remain single. On the one hand, married life yields the lifetime utility w. On the other hand, let the expected momentary utility for a matched single be $N(\pi)$, which is increasing in the odds of safe sex π. The function $N(\pi)$ is unpacked in the next section. The matched single will enter next period still single, which has the discounted continuation value of βS. Hence, the expected lifetime utility from single life is $N(\pi)+\beta S$. Clearly, a matched single will choose the option that yields the highest level of expected lifetime utility. The decision to marry in the current period can be cast as

$$\begin{array}{ll} \textsc{Marry}, & \text{if} \quad w \geq N(\pi)+\beta S; \\ \textsc{Remain Single}, & \text{if} \quad w < N(\pi)+\beta S. \end{array}$$

There will exist a threshold rule for w, denoted by w^*, such that

$$\begin{array}{ll} \textsc{Marry}, & \text{if} \quad w \geq w^*; \\ \textsc{Remain Single}, & \text{if} \quad w < w^*, \end{array}$$

where w^* is the solution to

$$w^* = N(\pi) + \beta S. \tag{1}$$

It is now easy to see that S satisfies the recursion

$$S = \underbrace{(1-\mu)\beta S}_{\text{unmatched}} + \underbrace{\mu E[\max\{N(\pi)+\beta S, w\}]}_{\text{matched}},$$

where recall that the marriage decision is made after the value for w is realized. The above recursion can then be rewritten as

$$S = (1-\mu)\beta S + \mu\{W(w^*)\underbrace{[N(\pi)+\beta S]}_{w^*} + \int_{w^*} w dW(w)\},$$

which implies that

$$S = \frac{\mu W(w^*)w^* + \mu \int_{w^*} w dW(w)}{1-(1-\mu)\beta}. \tag{2}$$

Therefore, using (1) and (2), at the threshold

$$w^* = N(\pi) + \beta\mu[\frac{W(w^*)w^* + \int_{w^*} w dW(w)}{1-(1-\mu)\beta}].$$

So how does contraception affect marriage? To see this, totally differentiate the above equation with respect to π and w^* to get

$$\frac{dw^*}{d\pi} = \frac{N_1(\pi)}{1-\beta\mu W(w^*)/[1-(1-\mu)\beta]} > 0.$$

In obtaining and signing this expression three facts are worth noting. First, the expected momentary utility for a matched single is increasing in the odds of safe sex, π, implying $N_1(\pi) > 0$–again, this will be established in the next section. Second, at the threshold $d\beta[\mu W(w^*)w^* + \mu \int_{w^*} w dW(w)]/dw^* = \beta\mu W(w^*)$. Third,

$$1-\beta\mu W(w^*)/[1-(1-\mu)\beta] = \big((1-\beta\{1-\mu[1-W(w^*)]\}\big)/[1-(1-\mu)\beta] > 0.$$

Intuitively speaking, when contraception becomes more effective there is a hike in the expected momentary utility for a matched single, $N(\pi)$; this is established below in Proposition 3. As a result, matched singles become choosier about who they will marry and the threshold value of love that has to be met for a marriage, w^*, moves up. The situation is portrayed in Figure 10. For a matched individual the value of marriage is just w. This is shown by the 45^0 degree line marked w. The expected lifetime value of life for a person who is currently single is shown by the line labelled $N(\pi) + \beta S$. This line is not a function of the realized value for w, as can be seen by inspecting equation (2). The threshold value for w, or w^*, at which the individual is indifferent between marriage and single life occurs where the w and $N(\pi)+\beta S$ lines intersect. Suppose that contraception improves; in other words, let π rise. The expected value of single life moves up, as shown by the shift in the curve from $N(\pi) + \beta S$ to $N(\pi') + \beta S'$. This fact is established below. The w curve does not shift, since the random draw for married life is not a function of π. As a result, the threshold value for marriage, w^*, increases

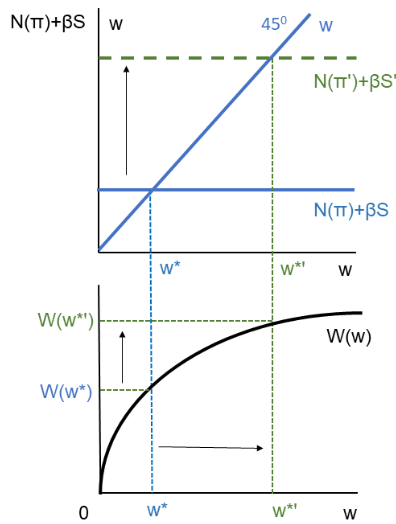

Figure 10: The determination of w^* and $W(w^*)$. The threshold for marriage, w^*, is determined where the $N(\pi) + \beta S$ and w lines intersect. To the left of w^* a person will choose single life, because the $N(\pi)+\beta S$ curve lies above the w one. To the right the opposite happens. An increase in the effectiveness of contraception, π, results in the $N(\pi) + \beta S$ curve shifting up to $N(\pi') + \beta S'$. As a consequence the threshold for marriage moves higher or rightward from w^* to $w^{*\prime}$. The fraction of matched singles choosing not to marry then rises from $W(w^*)$ to $W(w^{*\prime})$.

from w^* to $w^{*\prime}$. This causes the fraction of matched singles who choose not to marry to rise from $W(w^*)$ to $W(w^{*\prime})$. The above analysis is summarized by the proposition below.

Proposition 1 *(Marriage Rate) An improvement in contraception, or an increase in π, leads to a decline in the marriage rate, $1 - W(w^*)$, propelled by an increase in w^*.*

Interestingly, the expected lifetime utilities for both married and single lives, $\{1/[1-W(w^*)]\}\int_{w^*} wdW(w)$ and S, increase. For married life, it is straightforward to calculate that

$$\frac{d\big(\{1/[1-W(w^*)]\}\int_{w^*} wdW(w)\big)}{d\pi}$$
$$= \frac{1}{1-W(w^*)}[\frac{1}{1-W(w^*)}\int_{w^*} wdW(w) - w^*]W_1(w^*)\frac{dw^*}{d\pi} > 0,$$

where the term in brackets on the righthand side is greater than 0. The expected lifetime value of married life rises because the expected value of single life has improved. This allows singles to be pickier about their marriage partner. For single life, it follows from equation (2) that

$$\frac{dS}{d\pi} = \frac{\mu W(w^*)}{1-(1-\mu)\beta}\frac{dw^*}{d\pi} > 0.$$

This justifies the upward shift of the $N(\pi)+S$ curve, following an increase in π, that is shown in Figure 10–by assumption $N(\pi)$ is increasing in π. Single life improves because there is a boost in the expected momentary utility for a matched single, $N(\pi)$, due to the fact that premarital sex is now safer.

6 An Abstinent or Sexual NonMarital Relationship?

Consider the decision facing a matched single who has decided not to marry. An abstinent relationship yields a momentary utility value of a, while for a sexual one it depends on libido, l. At this time the person knows the value of l. On the one hand, a sexual endeavour leads to the thrill l. On the other hand, the person may become pregnant with probability $1-\pi$ and suffer the cost of an out-of-wedlock birth, O. Therefore, the expected momentary utility from a sexual relationship is $l - (1-\pi)O$.

The utility for a matched single who has decided not to marry and subsequently drawn a value for l is given by

$$\max\{a, l - (1-\pi)O\}.$$

Hence, the decision to have a nonmarital sexual relationship is described by

$$\begin{array}{ll} \text{Abstinent}, & l \leq a + (1-\pi)O; \\ \text{Sexual Relationship}, & l > a + (1-\pi)O. \end{array}$$

There will exist a threshold rule for l, denoted by l^*, such that

$$\begin{array}{ll} \text{Abstinent}, & \text{if} \quad l \leq l^*; \\ \text{Sexual Relationship}, & \text{if} \quad l > l^*, \end{array}$$

where l^* is given by

$$l^* = a + (1-\pi)O.$$

Therefore, the odds of abstinent and sexual relationships, contingent on being matched, are $L(l^*)$ and $1 - L(l^*)$. This implies that the fraction of singles having premarital sex is $\mu[1 - L(l^*)]$. As the efficacy of contraception, π, improves, the probability of an out-of-wedlock birth for a sexually active single drops. So, the expected cost, $(1-\pi)O$, of being sexually active declines. As a result, there will be more sexually active singles. Figure 11 illustrates the situation. The 45^0 line marked l in the upper panel is the benefit from premarital sex. The horizontal line labeled $a + (1-\pi)O$ represents the cost of premarital sex. This has two components; namely, the forgone value of abstinence, a, and the expected cost of an out-of-wedlock birth, $(1-\pi)O$. The threshold level of libido, l^*, is determined in the upper panel where the l and $a + (1-\pi)O$ lines intersect or where the cost and benefit of sex are equalized. The lower panel plots the cumulative distribution function $L(l)$. As such it gives the odds of abstinence, $L(l^*)$, conditional on a match. When contraception improves, the cost of premarital sex falls so that the $a + (1-\pi)O$ line moves down to $a + (1-\pi')O$, which results in l^* dropping to $l^{*\prime}$. The fraction of matched singles that pick abstinence declines from $L(l^*)$ to $L(l^{*\prime})$.

Proposition 2 *(Sexually Active Singles) The fraction of singles in a sexual relationship, $\mu[1 - L(l^*)]$, is increasing in the odds of safe sex, π.*

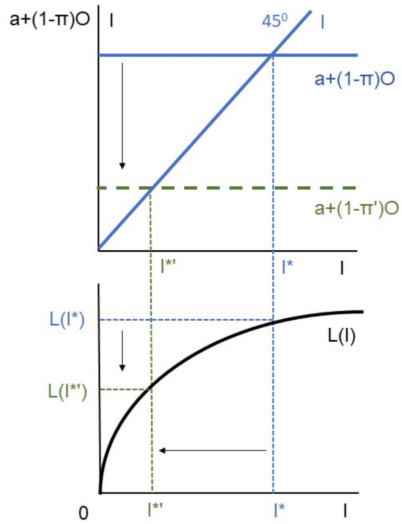

Figure 11: The determination of l^* and $L(l^*)$. The threshold level of libido, l^*, occurs where the l and $a + (1 - \pi)O$ lines in the upper panel intersect. An increase in π lowers the cost of premarital sex, so that $a + (1 - \pi)O$ shifts down to $a + (1 - \pi')O$. As a result, l^* drops to $l^{*\prime}$. The odds of abstinence for a matched single fall, consequently, from $L(l^*)$ to $L(l^{*\prime})$, as shown by the lower panel.

Proof. It's easy to see that

$$\mu \frac{1 - dL(l^*)}{d\pi} = \mu L_1(l^*)O > 0.$$

■

The expected momentary utility of not marrying for a matched single is

$$N(\pi) = L(l^*)a + \int_{l^*} l dL(l) - [1 - L(l^*)](1 - \pi)O.$$

The level of expected utility for a matched single improves with technological progress in contraception for two reasons. First, for a sexually active single the odds of an out-of-wedlock birth have declined. Second, a single is more likely to be sexually active, since $1 - L(l^*)$ rises, and having sex yields a higher level of expected utility than abstinence because $\int_{l^*} l dL(l) - (1 - \pi)O > a$.

Proposition 3 *(Current Utility for a Matched Single) The level of current expected utility for a matched single, $N(\pi)$, is increasing in the odds of safe sex, π; i.e., $N_1(\pi) > 0$.*

Proof. Differentiating with respect to π yields

$$\begin{aligned} N_1(\pi) = L_1(l^*)O[-a + l^* - (1 - \pi)O] + [1 - L(l^*)]O \\ = [1 - L(l^*)]O > 0, \end{aligned}$$

where use is made of the facts that $dL(l^*)/d\pi = -L_1(l^*)O$ and $l^* = a + (1 - \pi)O$. Therefore, the momentary expected value of being a matched single rises with the odds of safe sex, π. ■

7 Statistical Mechanics

7.1 Marriage by Age

How many people will be married by a given age in the population? Recall that each period a cohort of new adult singles enters the economy. This cohort initially has unit mass but its size atrophies over time according to the survival rate σ. Follow this cohort as it ages period by period. Suppose that at the end of period $j - 1$ there are s_{j-1} singles around from the cohort.

Marriage Statistics for a Cohort by Age				
Age	Newly Married, n	Remaining Single, s	Total Married, m	Surviving
1	$n_1 = \mu[1 - W(w^*)]$	$s_1 = 1 - \mu + \mu W(w^*)$	$m_1 = n_1$	1
2	$n_2 = \mu[1 - W(w^*)]\sigma s_1$	$s_2 = [1 - \mu + \mu W(w^*)]^2\sigma$	$m_2 = \sigma m_1 + n_2$	σ
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$
j	$n_j = \mu[1 - W(w^*)]\sigma s_{j-1}$	$s_j = [1 - \mu + \mu W(w^*)]^j \sigma^{j-1}$	$m_j = \sigma m_{j-1} + n_j$	σ^{j-1}

Table 1: The evolution of a cohort by age. Each period a new cohort of unit mass enters the economy. The table gives the fractions by age of the original cohort that are newly married, single, married, and surviving. In a steady state the total size of the population is $1/(1-\sigma)$. An entry in a cell also represents number of people in the population in the designated situation. To get the fraction of the population in this case just divide by $1/(1-\sigma)$.

Then, there will be σs_{j-1} singles around at the beginning of period j. Out of this, $\mu\sigma s_{j-1}$ people match implying that the number of marriages is

$$n_j \equiv \mu[1 - W(w^*)]\sigma s_{j-1}, \text{where } s_0 \equiv 1/\sigma.$$

The number of singles in the cohort will then evolve according to

$$s_j = \sigma s_{j-1} - n_j = [1 - \mu + \mu W(w^*)]^j \sigma^{j-1}.$$

The term on the right is easy to explain. If a person enters a period single, then the odds of them exiting the period single are given by $1-\mu+\mu W(w^*)$. On this the probability of not matching is $1-\mu$, while the probability of matching and not marrying is $\mu W(w^*)$. So, the odds of not marrying at the end of j periods are $[1-\mu+\mu W(w^*)]^j$ while the chance of surviving this long is σ^{j-1}. To summarize, the cohort evolves in the manner displayed in Table 1.

The impact of contraception on the married and never-married populations can now be analyzed. The fraction of the age-j population that is never married is

$$\frac{s_j}{\sigma^{j-1}},$$

while portion of the population up to and including age j that is never married is

$$\frac{\sum_{i=1}^{j} s_i}{\sum_{i=1}^{j} \sigma^{i-1}}. \tag{3}$$

Now suppose that the odds of safe sex, π, improve due to technological progress in contraception. From Proposition 3 single life becomes more enjoyable. Therefore, a matched single will become pickier about who they marry; that is, w^* rises from Proposition 1. The fraction of never-married individuals in the population at large moves up, as a consequence.

Proposition 4 *(Never-Married Population) The fraction of the population that is never married, as defined by (3), is increasing in the efficacy of contraception, π.*

Proof. Using the fact that $s_j = [1-\mu+\mu W(w^*)]^j \sigma^{j-1}$, it is immediate that

$$\frac{ds_j}{d\pi} = j[1-\mu+\mu W(w^*)]^{j-1}\sigma^{j-1}\mu W_1(w^*)\frac{dw^*}{d\pi} > 0,$$

where the sign follows from Proposition 1. ■

The average age of marriage for the age-j population is

$$\frac{\sum_{i=1}^{j} i n_i}{\sum_{i=1}^{j} n_i}. \tag{4}$$

One may conjecture that an increase in the efficacy of contraception will postpone the mean age of marriage because the rate of marriage at any age drops by Proposition 1. This is true, but the logic is not so straightforward because the number of the age-i newly married in the population, n_i, decreases in both the numerator and denominator of (4).

Proposition 5 *(Mean and Median Ages of Marriage) The mean and median ages of marriage are increasing in the efficacy of contraception, π.*

Proof. See the Theory Appendix. ■

7.2 Premarital Sex

Let v_{j-1} represent the size of the age-$(j-1)$ population that has never had sex. The size of the age-j populace that hasn't had sex is then given by $v_j = [1-\mu+\mu W(w^*)L(l^*)]\sigma v_{j-1}$, where $v_0 \equiv 1/\sigma$. To understand this expression, first note that only σv_{j-1} of the original age-$(j-1)$ virgin population will survive until age j. Second, out this the fraction $1-\mu$ will remain unmatched. The proportion μ will match, but from this segment the fraction $W(w^*)L(l^*)$ will choose both not to marry and not to have sex with their partner. Therefore, the fraction of the age-j population that has never had sex is

$$\frac{v_j}{\sigma^{j-1}}.$$

Now,

$$\frac{d(v_j/\sigma^{j-1})}{d\pi} = j\{1-\mu+\mu W(w^*)L(l^*)\}^{j-1} \times \mu\{W_1(w^*)L(l^*)\underbrace{\frac{dw^*}{d\pi}}_{+} + W(w^*)L_1(l^*)\underbrace{\frac{dl^*}{d\pi}}_{-}\} \gtreqless 0.$$

This expression is ambiguous because while safer sex leads to a decrease in the number of age-j singles who are abstinent, via a drop in the threshold level of libido, l^*, it also increases the pool of age-j singles, through a rise in the threshold value for marriage, w^*.

Additionally, there are age-j marrieds who didn't have premarital sex. For example, at age j there will be $\mu[1-W(w^*)]\sigma v_{j-1}$ individuals who marry but didn't have premarital sex. So, the fraction of the age-j population that didn't have premarital sex is

$$\frac{v_j + \mu[1-W(w^*)]\sum_{i=1}^{j}\sigma^{j+1-i}v_{i-1}}{\sigma^{j-1}}.$$

The fraction of the age-j single population that has never had sex is

$$\frac{v_j}{s_j} = \frac{[1-\mu+\mu W(w^*)L(l^*)]^j\sigma^{j-1}}{[1-\mu+\mu W(w^*)]^j\sigma^{j-1}} = [\frac{1-\mu+\mu W(w^*)L(l^*)}{1-\mu+\mu W(w^*)}]^j.$$

Proposition 6 *(Premarital Sex) The fraction of the age-j single population, $1-v_j/s_j$, that has had premarital sex is increasing in the odds of safe sex, π.*

Proof. The proposition holds because

$$\frac{d(v_j/s_j)}{d\pi} = j[\frac{1-\mu+\mu W(w^*)L(l^*)}{1-\mu+\mu W(w^*)}]^{j-1}\mu$$
$$\times\frac{[1-\mu+\mu W(w^*)]W(w^*)L_1(l^*)dl^*/d\pi-(1-\mu)W_1(w^*)[1-L(l^*)]dw^*/d\pi}{[1-\mu+\mu W(w^*)]^2}<0.$$

■

7.3 Number of Sexual Partners

A variable of interest is the average number of premarital sexual partners that an age-j person has. Let p_j^i be the number of singles that have had i sexual partners by age j. First, given the model's timing structure, $p_j^i = 0$ for $i > j$. Second, for an age-j single to have 0 sexual partners they must have had 0 sexual partners at age-$(j-1)$, survive into period j with chance σ, and then either remain unmatched with probability $1-\mu$ or match with odds μ, decide not to marry with likelihood $W(w^*)$, and not to have premarital sex with chance $L(l^*)$. Therefore, $p_j^0 = \sigma p_{j-1}^0[1-\mu+\mu W(w^*)L(l^*)]$. Likewise, for an age-$j$ single to have j sexual partners they must have had $j-1$ sexual partners at age-$(j-1)$ which happens with probability p_{j-1}^{j-1}, survive with chance σ, then match and remain single in period j with odds $\mu W(w^*)$, and finally decide to have sex with probability $1-L(l^*)$. This implies $p_j^j = \sigma\mu W(w^*)[1-L(l^*)]p_{j-1}^{j-1}$.

Finally, there are exactly three ways for an age-j single to have i sexual partners, where $i < j$. First, they could have had $i-1$ partners at age $j-1$, survive, match and remain single, and then have decide to have sex. There will be $\sigma\mu W(w^*)[1-L(l^*)]p_{j-1}^{i-1}$ people in this category. Second, they could have had i sexual partners in period $j-1$, survive, but not match. There will be $\sigma(1-\mu)p_{j-1}^i$ such singles. Third, they could have had i sexual partners in period $j-1$, survive, match, remain single, and decide not to have sex. The number of singles here is $\sigma\mu W(w^*)L(l^*)p_{j-1}^i$. Hence, $p_j^i = \sigma\{\mu W(w^*)[1-L(l^*)]p_{j-1}^{i-1} + [(1-\mu)+\mu W(w^*)L(l^*)]p_{j-1}^i\}$.

The number of sexual partners that a person has before marriage can be computed using the statistics in the above table. Let q_j^i be the number of

Statistics on the Number of Singles with i Sexual Partners by Age j					
	Sexual Partners				
	0	1	2	$\cdots$	j
Age 1	$p_1^0 = 1 - \mu + \mu W(w^*)L(l^*)$	$p_1^1 = \mu W(w^*)[1 - L(l^*)]$	$p_1^2 = 0$	$\cdots$	$p_1^j = 0$
Age 2	$p_2^0 = \sigma p_1^0[1 - \mu + \mu W(w^*)L(l^*)]$	$p_2^1 = \sigma\{\mu W(w^*)[1 - L(l^*)]p_1^0 + [(1-\mu) + \mu W(w^*)L(l^*)]p_1^1\}$	$p_2^2 = \sigma\mu W(w^*)[1 - L(l^*)]p_1^1$	$\cdots$	$p_2^j = 0$
$\vdots$	$\vdots$	$\vdots$	$\vdots$		$\vdots$
Age j	$p_j^0 = \sigma p_{j-1}^0[1 - \mu + \mu W(w^*)L(l^*)]$	$p_j^1 = \sigma\{\mu W(w^*)[1 - L(l^*)]p_{j-1}^0 + [(1-\mu) + \mu W(w^*)L(l^*)]p_{j-1}^1\}$	$p_j^2 = \sigma\{\mu W(w^*)[1 - L(l^*)]p_{j-1}^1 + [(1-\mu) + \mu W(w^*)L(l^*)]p_{j-1}^2\}$	$\cdots$	$p_j^j = \sigma\mu W(w^*) \times [1 - L(l^*)]p_{j-1}^{j-1}$

Table 2: The distribution over the number of premarital sexual partners that singles have at each age.

age-j married people that have had i partners before marriage. First, to have had $j-1$ partners by age j you must have had $j-1$ partners while single up to age $j-1$, survived to age j, and then gotten married. So, the number of age-j married people who have had $j-1$ partners is $q_j^{j-1} = \sigma\mu[1 - W(w^*)]p_{j-1}^{j-1}$.

Second,

$$q_j^i = \sigma\mu[1 - W(w^*)]p_{j-1}^i + \sigma^2\mu[1 - W(w^*)]p_{j-2}^i + \cdots + \sigma^{j-i}\mu[1 - W(w^*)]p_i^i,$$

for $0 < i \leq j-1$ and $p_0^0 \equiv 0$. On this, note that the earliest you can have i partners is at age i. At age i there will be p_i^i such singles. Out of this group, $\sigma\mu[1 - W(w^*)]p_i^i$ will marry at age $i+1$ and then survive to period j with probability σ^{j-i-1}. Likewise, p_h^i singles of age h, for $i \leq h \leq j-1$, will have had i partners at age h, then gotten married at age $h+1$ with probability $\sigma\mu[1 - W(w^*)]$, and subsequently survived to age j with probability σ^{j-h-1}.

Last, for an age-j married person to have 0 sexual partners they must have survived until age j and gotten married without having premarital sex. They could marry at any age up to and including j. Thus, to summarize

$$q_j^i = \mu[1 - W(w^*)]\sum_{h=i}^{j-1}\sigma^{j-h}p_h^i, \text{ for } 0 \leq i \leq j-1, \tag{5}$$

where $p_0^0 \equiv 1/\sigma$. Empirically, it may be desirable to include the person that you marry as a partner.

Now, the average number of sexual partners that an age-j married person has is

$$\frac{\sum_{i=0}^{j} iq_j^i}{\sum_{i=0}^{j} q_j^i} = \frac{\sum_{i=0}^{j} iq_j^i}{m_j}, \tag{6}$$

where m_j is the total number of people who are married at age j as defined in Table 1. A reasonable conjecture might be that the average number of premarital partners that an age-j married person has is increasing in the efficacy of contraception, π. While this can't be established theoretically speaking, it still can be true quantitatively.

7.4 Out-of-Wedlock Births

The fraction of matched singles that have an out-of-wedlock birth is $(1-\pi)[1-L(l^*)]$. This can rise or fall with π, depending on whether

$$\underbrace{-[1-L(l^*)]}_{\text{IMPROVED CONTRACEPTION}} + \underbrace{(1-\pi)\frac{1-dL(l^*)}{d\pi}}_{\text{INCREASE IN SEXUAL ACTIVITY}} \gtreqless 0.$$

This is an elasticity question that can be rephrased as

$$\frac{(1-\pi)}{[1-L(l^*)]}\frac{1-dL(l^*)}{d\pi} \gtreqless 1.$$

The shape of the distribution function $L(l)$ will determine whether out-of-wedlock births for matched singles rise or fall with the odds of safe sex, π.

For the population at large, equation (3) gives the fraction who have not married by age j. Out of this group, the portion μ will be matched in the current period. The fraction $1-W(w^*)$ will marry, while the slice $W(w^*)$ won't. Therefore the fraction of the nonmarried population that will be matched and remain single is given by $\mu W(w^*)/\{1-\mu[1-W(w^*)]\}$. Out of this, the cut $1-L(l^*)$ will be sexually active. Consequently, given the failure rate, $1-\pi$, the fraction of the population up to and including age j that currently has an out-of-wedlock birth is

$$(1-\pi)[1-L(l^*)]\frac{\mu W(w^*)}{1-\mu[1-W(w^*)]}\frac{\sum_{i=1}^{j} s_i}{\sum_{i=1}^{j}\sigma^{i-1}}. \tag{7}$$

Clearly, this can rise or fall with π, because, as was just shown, $(1-\pi)[1-L(l^*)]$ can rise or fall in π.

8 Calibration

8.1 The Procedure

The quantitative analysis focuses on two periods, namely 1900 and 2000. A steady state for the model is computed for each of these periods. The model period is taken to be three months (or a tertile). Functional forms for the distribution functions governing libido, l, and marriageability, w, need to be chosen. Let libido be governed by a Weibull distribution. Specifically,

$$L(l) = 1 - \exp[-(l/\lambda)^{\eta}], \text{ for } \lambda, \eta > 0,$$

where λ and η are the scale and shape parameters, respectively. Assume that marriageability has an exponential distribution. In particular,

$$W(w) = 1 - \exp[-(w/\xi)], \text{ for } \xi > 0.$$

Here ξ is the mean of the marriageability distribution.

Two criteria are used for selecting parameter values. First, the values for some parameters can be assigned from a priori information. Second, the remaining parameters values are chosen so that the model matches, as well as possible, a set of data targets. Start with the parameters chosen on the basis of a priori information. Denote the discount factor, sans the survival rate, by δ. Given this, $\beta = \sigma\delta$. The discount factor, δ, is given the standard value of $0.96^{1/3}$. People are assumed to have a life span relevant for marriage decisions of 30 years. The three month survival rate, σ, is set at $0.9924^{1/3}$ for 1900 and $0.9997^{1/3}$ for 2001.[3] The failure rates for contraception are taken directly from the data, as discussed below. Last, the mean for marriageability distribution, or ξ, is just a normalization. On this, suppose that a solution to the model has been found for some value of ξ. The same solution obtains for $\phi \times \xi$ if $a, O,$and λ are also multiplied by $\phi > 1$. What matters for an individual's choices are the relative values of abstinence, premarital sex, and marriage. So, set $\xi = 1.0$.

The values for the rest of the parameters are selected to hit a set of stylized facts. Let D_j represent the jth data target. Likewise, $P_j(\rho)$ is the model's prediction for the jth target, as a function of the parameters, $\rho \equiv (a, \mu, O, \lambda, \eta)$, to be selected. These parameter are picked to minimize the

[3]These are in line with the numbers for 20- to 45–year-old women reported in the CDC's National Vital Statistics Reports.

relative predictions error of the model. Therefore, ρ solves the minimization problem

$$\min_{\rho} \sum_{j=1}^{18} \omega_j [\frac{D_j - P_j(\rho)}{D_j}]^2, \tag{8}$$

where ω_j is the weight placed on target j. The set of targeted stylized facts is (where $\omega_j = 1$ unless indicated otherwise):

1. The median age of marriage.

2. The fraction of women by age group who had ever been married in 1900 and 2000. Each age group for a year has a weight of 1/3.

3. The fraction of women by age group who had premarital sex in 1900 and 2004. Again, each age group for a year is weighted by 1/3.

4. The number of out-of-wedlock births per 1,000 unmarried women in 1920 and 1998.

5. The number of partners (including future husband) before marriage in 1900 and 2000.

The parameters values that result from the calibration procedure are listed in Table 3. All parameters values are kept constant across the two steady states, except for the failure rate of contraception, which is discussed now.

8.2 The Failure Rate for Contraception, 1900 to 2015-2018

An important ingredient for the quantitative analysis is the failure rate for contraception. Figure 12 shows the dramatic decline in the failure rate for contraception starting in 1900 and moving forward to 2015-18. The failure rate gives the odds of a woman becoming pregnant if she has sex at the normal frequency for a period of one year. For each year the series harnesses the frequency distribution over the contraceptive practices used by women. This will depend on both the contraception technologies that are available at the time and their diffusion among sexually active women. The latter

Parameter Values			
Parameter	Value, 1900	Value, 2000	Description
Set using ex ante information			
J	90	90	# of periods
ι	3	3	periodicity, months
δ	$0.96^{1/3}$	$0.96^{1/3}$	discount factor
σ	$0.9924^{1/3}$	$0.9997^{1/3}$	survival rate
π	$(1-0.72)^{1/3}$	$(1-0.18)^{1/3}$	Pr(safe sex)
ξ	1.0	1.0	exponential, mean–w
Set via calibration routine			
λ	22.7229	22.7229	Weibull, shape–l
η	0.027	0.027	Weibull, scale–l
a	0.027	0.027	abstinence
O	0.1806	0.1806	out-of-wedlock birth
μ	0.3359	0.3359	matching rate

Table 3: Parameter Values. The parameters set on the basis of ex ante information are discussed in the text. The remaining parameters are selected in line with the minimization routine (8).

depends upon the dissemination of information about, and the dispensation of, contraception. It also takes into account that some women won't use any method, including just withdrawal. Then, to compute the overall failure rate, the failure rate for each contraception is averaged across the different practices using the observed frequency distribution for usage. As can be seen, engaging in premarital sex in 1900 would have been very risky given the 72 percent odds of pregnancy. By 2015-18, this had dropped to 18 percent. Further detail on the construction of the failure rates is provided in the Data Appendix.

8.3 Findings

The upshot of the calibration procedure is presented in Table 4. First, between 1900 and 2000 the median age of marriage in the United States rose from 21.9 to 25.1 years. The model does a good job replicating this fact, with the mean age of marriage moving up from 21.15 to 25.44. In the United States there is big drop between 1900 and 2000 in the percentage of 15- to

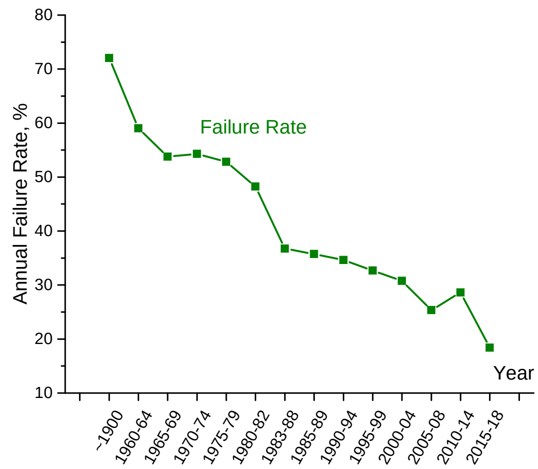

Figure 12: The annual failure rate for contraception, 1900 to 2015-18. The failure rate series is predicated upon the contraceptive technologies available at each point in time as well as the usage distribution by women.

24-year-old women that were ever married; an 11 percentage point drop from 29.62 to 18.17 percent. The model also displays an 11 percentage drop, but too many women are married in this age group. Additionally, in the model for the year 2000 too few women have been married in the 25-to-34 and 35-to-44 age groups.

Second, single women became much more sexually active between 1900 and 2000. In the U.S. data for 1900, only 8 percent of women had experienced premarital sex by age 20, 14 percent by age 25, and still only 26 percent by age 30. The model mimics this low level of sexual activity well, with the corresponding numbers being 12, 18, and 21 percent. It over predicts the rise in premarital sexual activity. In the 2000 data 76 percent of women had engaged in premarital sex by age 20, a rise of 68 percentage points, while in the model 94 percent did, which represents an increase of 82 percentage points.

Third, over the period in question out-of-wedlock births in the United States shot up from 8.7 per 1,000 single women to 44.3. There is also a large increase in the model from 3.4 to 33.6. This represents an increase in the data of 35.6 pregnancies per 1,000 single women and an increase of 30.2 for the model. Additionally, single women now have sex with more partners than

Data Targets				
Description	Data, ∼1900	Model, 1900	Data, ∼2000	Model, 2000
Marriage				
Median Age	21.9	21.15	25.1	25.44
Ever Married, %				
Age 15-24	29.62	34.93	18.17	23.95
Age 25-34	77.42	73.77	70.25	56.36
Age 35-44	88.90	89.43	86.60	74.96
Premarital Sex, %				
By Age 20	8	12	76	94
By Age 25	14	18	87	95
By Age 30	26	21	87	95
O.w.b.'s per 1,000 Singles	8.7	3.40	44.3	33.6
Partners before Marriage	2.8	1.18	7.0	8.2

Table 4: Data Targets. All statistics are for women. Data sources are detailed in the Data Appendix.

in the past. In 1900 women on average had 2.8 partners before marriage, including her future husband. The corresponding figure in the model is 1.2, when the future husband is also counted. This rose to 7.0 partners in the 2000 data and to 8.2 for the model. Overall, the model does a good job explaining the targeted set of facts. The relationship between parameter values and data targets is inspected by computing the Jacobian for the model. At the calibrated equilibrium, the parameter values affect premarital sex in 1900 more than in 2000. This makes sense because almost nobody had premarital sex in 1900 while most 20 year olds have experienced it today. Likewise, the parameter values have a bigger impact on marriage in 2000 vis à vis 1900. By similar reasoning, this transpires because marriage was much more prevalent in 1900 than today.

8.4 Opening the Black Box

The impact that parameter values have on the data targets can be analyzed by computing the model's Jacobian. The response of a data target to a displacement in the value of a parameter is calculated in elasticity form; i.e.,

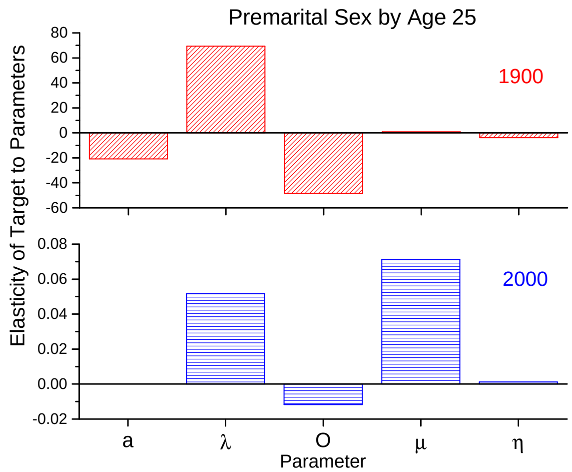

Figure 13: The part of the Jacobian showing the response of the percentage of women who had premarital sex before age 25 to a displacement in the parameters. The Jacobian is presented in elasticity form. Note that the units on the vertical scale for 1900 are much larger than the ones for 2000.

$[\rho_i/P_j(\rho)] \times dP_j(\rho)/d\rho_i$ is computed for all i and j in (8). It turns out that (locally) a, μ, O, λ, and η have a large effect on sexual behavior in 1900, but little impact on such behavior in 2000. By contrast, the marriage statistics for 2000 display a bigger response to shifts in the parameters than do the ones for 1900.

Figure 13 shows how the percentage of women who had premarital sex by age 25 responds in the two steady states to a change in parameter values. The impact of a movement in parameter values is much larger for the 1900 steady state than for the 2000 one, as can be seen by the units on the vertical axes. In 2000 almost all matched singles in the model are having premarital sex so the reaction is muted, while for 1900 a small minority are so the response is much bigger. The reactions make sense too. For example, increasing the utility from abstinence, a, or the cost of an out-of-wedlock birth, O, reduce the amount of premarital sex in 1900. Raising the libido shape parameter, λ, which increases the flow of women into premarital sex given the threshold, results in a higher level of premarital sex. The utility level for abstinence, a, has a negligible impact on premarital sex in 2000, because almost no matched singles are abstinent.

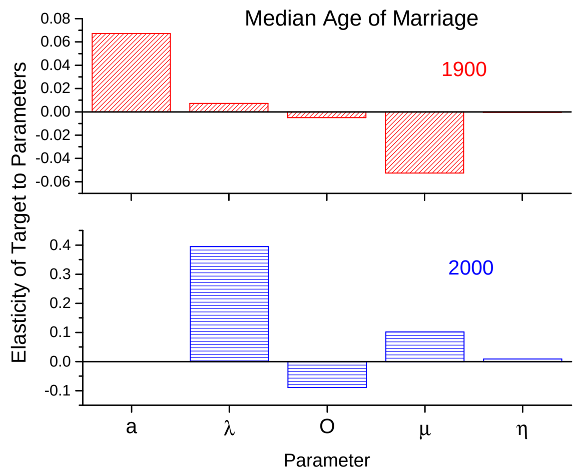

Figure 14: The part of the Jacobian showing the response of the median age of marriage to a displacement in the parameters. The Jacobian is presented in elasticity form. Note that the units on the vertical scale for 2000 are much larger than the ones for 1900, the opposite of Figure 13.

Figure 14 does the same thing for the median age of marriage. Now a displacement in the parameter values has a much larger impact on the 2000 steady state than for the 1900 one, as can be seen by the units on the vertical axes. This makes sense. In the 2000 steady state the vast majority of matched singles choose to have a sexual relationship. So, for example, they respond to an increase in the cost of out-of-wedlock births, O, by moving into marriage (or marrying earlier). A rise in the matching rate, μ, leads to a delay in marriage for the 2000 steady state, but entices people to marry just slightly earlier in the 1900 one. This transpires because in the 2000 steady state the cost of waiting is lower because people can engage in non-marital sexual relationship. This opportunity is more costly in the 1900 steady state, so people are less picky about their mate, and hence marry earlier.

9 Conclusions

While fertility has been controlled for eons, premarital sex would have been too risky for women historically. This began to change in the 19th century when contraceptive technology improved and information about contraception disseminated (Section 3). The 19th and 20th century saw improvements in condoms and spermicides, and the introduction of diaphragms, IUDs, and the pill. Just as important was the dissemination of information about contraception, often at personal risk for the providers. In America this started and ended with the crusaders Dr. Charles Knowlton and Margaret Sanger. The hypothesis here is that advancement in contraception led to a rise in premarital sex, an increase in out-of-wedlock births, and a fall in the fraction of population that is married population.

To address this hypothesis a marital search model is constructed. Each period a single may meet a partner. A person can choose to marry their partner or not (Section 5). If not, they can decide whether to have a premarital sexual relationship with the person (Section 6). The risk of a premarital sexual relationship is an out-of-wedlock birth. As contraception improves this risk is mitigated. It is shown theoretically that a drop in the failure rate for contraception leads to a decline in the rate of marriage (Section 5), an increase the fraction of singles who are sexually active (Section 6), a rise in the proportion of the population that is never married (Section 7), and delay in the average age of marriage (Section 7).

The theoretical model is then confronted with the U.S. data (in Section 8). The quantitative analysis focuses on two periods in U.S. history; viz, 1900 and 2000. To start with, a time series is constructed measuring the efficacy of contraception. It is shown that the odds of a pregnancy for a sexually active women dropped dramatically between 1900 and 2015-18. This made sex much safer for singles. The question then asked is whether the model can explain, as a function of technological progress in contraception the following set of facts: the observed decline in marriage between 1900 and 2015-18, the rise in premarital sex, the increase in out-of-wedlock births, and the uptick in the number of sexual partners before marriage that occurred. The answer is yes.

A review of the relevant economics literature on marriage is presented now.

10 Literature Review

10.1 Contraception and the Age of Marriage

> An increasing use of birth control may be a cause of earlier marriage. For if a young couple can contemplate a marriage without a baby within a year, and hence with only two to provide for, and perhaps with the bride working at a paying job, we think there would be more marriage than if a baby is pretty sure to come within a year and the mother unable to earn any money.
>
> Against this argument is the idea held by some that a young woman practicing birth control could have sexual intercourse without marrying and without becoming a mother, hence she can have a man without marrying; and similarly a man can have a woman without marriage. Thus marriage might be discouraged by the spread of birth control. Ogburn and Nimkoff (1955, pp. 89-90)

As a theoretical proposition, Ogburn and Nimkoff (1955) thought that the impact of contraception on the age of marriage could go either way. While they note that "(i)t is very difficult to test these ideas with data," they felt that the first hypothesis had more currency given that the age of marriage was decreasing at the time–note the dip in the median age of marriage between 1940 and 1960 shown in Figure 1. Goldin and Katz (2002) advance a more modern version of this idea. They highlight two ways in which better contraception, the pill, changed the lives of college-educated women in the United States. First, the pill made the returns to investment in professional careers, such as law and medicine, less uncertain by allowing women to better time their fertility decisions. Second, the pill had a thicker marriage market effect: as more women delayed their entry into marriage, each individual woman became less concerned about being left out in the marriage market due to her career choice. In their empirical analysis, Goldin and Katz (2002) exploit variations across U.S. states in the access of young unmarried women to the pill. Their "most persuasive evidence for a role of the pill is that its initial diffusion among single women coincided with, and is analytically related to, the increase in the age at first marriage and the increase in women in professional degree programs" (p. 767).

Now, it is clear that fertility was under control well before the 1960s, as Figure 4 showed. This is not to say that family planning policies, especially for developing countries, are not important.[4] Also, the number of sexually-active single women had risen dramatically before this time–Figure 3. Furthermore, you can go to professional school while married. This is more common outside of the United States. The take off in women going to professional schools started after 1972. The flow of women into higher education has started well before this though. By 1972, 42 percent of bachelors degrees, 41 percent of masters degrees, and 18 percent of doctorates went to women, which amounted to 42 percent of all non-professional degrees. The respective numbers in 1900 were 19 percent, 19 percent, 8 percent, and 19 percent. The year 1972 was also when Title IX of the Education Amendments was signed into law. The law prohibited discrimination against women in any federally-funded education programs. Goldin and Katz (2002) defense is that its guidelines were not complete until 1975. While Title IX's statutory language was brief, it still would have been law upon enactment in 1972. It's likely that colleges and universities changed their admission policies before 1975, especially since there was uncertainty about what they would be legally liable for. In fact, one could argue that the passage of Title IX was itself a reaction to the changing place of women in education and the workplace. On this, see Greenwood, Guner, and Vandenbrouke (2017) for a model where the passage of women's rights is an endogenous function of the state of the economy. Last, Myers (2017), who revisits the empirical analysis by Goldin and Katz (2002), finds that the pill itself had little effect on the age of first marriages and births, while liberalized access to abortion had a much larger effect. So, the power of the pill, while important, may be overstated.

Before the pill was available to unmarried women, between its approval by the FDA in 1960 and the late 1960s or early 1970s, only married women could access it. Indeed, many U.S. states reduced the legal age of marriage from 21 to 18 during this period. According to Edlund and Machado (2015), these changes allowed women to marry early, which would be in line with Ogburn and Nimkoff's (1955) first idea. Combined with the pill, however, this also allowed them to widen the window between marriage and first birth and improve educational and professional outcomes. Gershoni and Low (2018a) document how the availability of in vitro fertilization in Israel has led to an increase in average age at first marriage. In related work, Gershoni and Low

[4] Cavalcanti, Kocharkov, and Santos (2019) introduce unwanted births into a model of fertility decisions and growth, and show that family planning programs, which reduce the number of unwanted pregnancies, can generate significant gains in the educational attainments of children and hence GDP.

(2018b) discuss how this increased education levels for women and resulted in higher paying careers. (Interestingly, Ogburn and Nimkoff (1955) discuss the transplantation of ova in their book, but speculated that its effect on the family would be negligible.)

10.2 Premarital Sex and Out-of-Wedlock Births

Technological advance in contraception allowed women to separate sex from marriage. This led to a dramatic increase in the fraction of women who engaged in premarital sex during the 20th century; again see Figure 3. Yet, despite the improvements in contraceptive technology, out-of-wedlock births increased as well. Greenwood and Guner (2010) study premarital sex among teenagers within the context of an equilibrium matching model. In the model individuals rationally weigh the costs and benefits from this risky activity. Better contraceptives lower the expected cost of premarital sex. In their quantitative analysis better contraceptives result in both an increase in the fraction of teenagers having sex and the fraction of them becoming pregnant. Akerlof, Yellen, and Katz (1996) also focus on this puzzle. They suggest that better contraceptives, coupled with the availability of abortion, led to the disappearance of shotgun marriages, and as a result there was an increase in out-of-wedlock first births. In their framework prior to a sexual relationship single women may or may not ask for an implicit promise of marriage in the event of pregnancy. With the advance of contraception and the legalization of abortion, men can choose among many sexually active single women. Some single women who become pregnant may be willing to have an abortion, others won't. Competition on the marriage market may lead to women who are opposed to abortion being reluctant to ask for such a promise. But, why would men abide by such an *implicit* promise? (I.e., their equilibrium is not subgame perfect.) This is left unanswered in Akerlof, Yellen, and Katz (1996).

One explanation might be that premarital sex and out-of-wedlock births were stigmatized in yesteryear. Fernandez-Villaverde, Greenwood, and Guner (2014) model the formation and evolution of such social norms. As premarital sexual activity became safer, parents, churches, and governments had less incentive to stigmatize premarital sex, given that socialization is a costly activity. Fernandez-Villaverde, Greenwood, and Guner (2014) formalize this intuition in a model of intergenerational preference transmission. For models of preference transmission in other contexts, see Becker (1993), Bisin and

Verdier (2001), and Doepke and Zilibotti (2008).

On the basis of the observed decline of shotgun weddings, Kennes and Knowles (2019) argue that an important ingredient in the rise of out-of-wedlock births is an increase in the value of single life (with children) relative to marriage. Their vehicle for analysis is a repeated-matching model where women are heterogeneous in the number of previous children and where singles make decisions each period regarding their sexual activity, birth control, abortion, and whether to marry if pregnant. Low take-up rates of the pill and the availability of abortion are critical features in their analysis. Kennes and Knowles (2019) consider a number of candidates, such as the advent of legal abortion, lower divorce costs, and increased frictions in shotgun weddings, that might be responsible for the decline in shotgun marriages. Other things might also have reduced the value of marriage relative to single life: more generous welfare benefits, rising living standards together with the advent of labor-saving household technologies, and a lessening of the stigma associated with an out-of-wedlock birth.

10.3 Other Factors Affecting the Timing of Marriage

Clearly factors other than contraceptives affect the timing of marriage. Browning, Chiappori, and Weiss (2014), Greenwood, Guner, and Vandenbroucke (2017), and Stevensen and Wolfers (2007) provide reviews of the literature.

10.3.1 Rising Wages

In his classic treatment of the topic, Becker (1991, p. 350) states that "the family in the United States changed more rapidly (since 1950) than during any equivalent period since the founding of colonies. I believe that a major cause of these changes is the growth in the earning power of women as the American economy developed." Higher relative earnings reduce the gains from marriage for women and allows them to be more choosy. Regalia and Rios-Rull (2001) formalize this idea in a quantitative model and show that increases in the relative earnings of women can potentially account for almost ninety percent of the observed rise in the share of single women since the mid-1970s. Shephard (2019) also focuses on the effects of a narrowing gender wage gap on marital outcomes. He builds a rich life-cycle equilibrium model with endogenous human capital accumulation, fertility, and home production to study time allocation and marriage decisions. His simulations show that decline in the gender wage gap since the 1980s is able to generate an increase in female employment, a decline in male employment, an increase in the age-of-first marriage for women, and a reduction in the marital age gap between men and women.

Other aspects of wage structure can also affect the incentive to get married. Olivetti (2006) documents that the returns to labor market experience increased for women since the 1970s and this was an important factor for the rising female labor supply. Caucutt, Guner, and Knowles (2002) show that, within a matching model of marriage, this will also increase the incentives of women to delay both fertility and marriage. Santos and Weiss (2016), instead, focus on the rising labor income volatility since the 1970s, and show that if marriage involves consumption commitments, such as children or housing, then a rise in income volatility will delay entry into marriage.

10.3.2 Household Technologies

Another key force that shaped families in the United States and elsewhere was the dramatic improvements in households technologies. Improvements in household durables freed women from housework and allowed them to enter the labor force–see Greenwood, Seshadri and Yorukoglu (2005). (Relatedly, Albanesi and Olivetti, 2016, argue that advances in maternal medicine facilitated the entry of young women into the workplace.) These forces reduced the benefits from traditional marriages; to wit, a breadwinner husband and a housekeeper wife. Greenwood and Guner (2009) integrate home production into a search model of marriage, and show that better household technologies can account for a significant part of the rise in divorce, the fall in marriage, and the increase in married female labor-force participation that occurred during the later half of the twentieth century. According to Greenwood and Guner (2009, p. 233), "the reduction of the economic benefits of marriage allowed the modern criteria of mutual attraction between mates to come to the fore, a trend 'from economics to romance' in the words of Ogburn and Nimkoff (1955)." They also show how improvements in household technology and increases in income can explain the increase in marriage between 1940 and 1960–for one more time, recall Figure 1.[5]

[5] The idea is that technological progress in the household sector, together with rising living standards, at first made it easier for young couples to leave their parents' homes and establish married households and then later on in time for singles to leave their parents's homes and establish single households before marriage. That is, there is a trend over time

As marriage declined in the United States, there has also been a rise in assortative mating, the tendency of people with similar educational attainments to marry each other (Chiappori, Selanie, and Weiss, 2017, and Greenwood, Guner, Kocharkov, and Santos, 2014). Greenwood, Guner, Kocharkov, and Santos (2016) develop a model, with heterogenous agents, of marriage, divorce, educational attainment, and married female labor-force participation. They show how a rise in the college premium together labor-saving technological progress in the household sector, led to a decline marriage, an increase married female labor-force participation, and widening inequality in the United States. The induced changes in labor-force participation and marriage play an important role in amplifying the impact of shifts in the wage structure on inequality.

10.3.3 The Welfare State

The expansion of welfare state, in particular social assistance to single mothers with children, has often been pointed to as another important force that has shaped U.S. families. There are mixed views about this idea. The empirical evidence in favor of the idea, which relies on cross-time and cross-state variations in welfare policies, has been weak–see Moffitt (1992) for an early review and Moffitt, Pheland, and Miller (2019) for a more recent analysis. Structural models such as Aiyagari, Greenwood, and Guner (2000) and Greenwood, Guner, and Knowles (2000) predict that less generous welfare payments should reduce the number of single woman. In line with this prediction, Low, Meghir, Pistaferri, and Voena (2018) show that the 1996 welfare reform did result in more women remaining married.

10.3.4 Lack of Marriageable Men

A large literature in sociology and demography, emphasizes the lack of marriageable men as a potential factor for the decline of marriage in the United States. The basic idea, following Wilson and Neckerman (1987), is that low wage growth, declining manufacturing, and rising incarceration in recent decades made marriageable men scarce. Shneider, Harknett, and Stimpson (2018) document, for example, that reduced economic prospects and increased risk of incarceration contributed significantly to the decline of marriage in the United States over the last 45 years. Incarceration has also been

toward smaller and smaller households.

proposed as a factor that can explain why blacks marry at a much lower rate than whites in the United States. Exploiting data cross-state U.S. states, Charles and Luoh (2010) find a strong negative effect of male incarceration rates on the likelihood of women ever getting married. Building on this intuition, Caucutt, Guner, and Rauh (2018) develop an equilibrium search model of marriage, divorce, and labor supply that takes into account the transitions between employment, unemployment, and prison for individuals by education, gender, and race. They show that if black men had the same employment and prison transitions as whites, then about half of the racial marriage gap would be eliminated.

10.3.5 Changes in the Sex Ratio

Since historically it took two sexes, a man and a woman, to form a marriage, the sex ratio (defined as the number of single men to single women) can affect marriage decisions. If there is an imbalance in the sex ratio, whoever is on the short side of the market will have a harder time to find a partner. When a marriage is formed, the sex in short supply will have a higher bargaining power. These features emerge in standard search and matching models (e.g., Greenwood, Guner, and Knowles 2000).

What can generate an imbalanced sex ratio? Some candidates are changes in population growth rates (say a baby boom or baby bust), male incarceration, sex-biased migration, and wars. Angrist (2002) exploits variations in migration flows as a natural experiment during the early 20th century in the United States. He finds that migration, which increased the size of the male population more for some ethnic groups than others, improved marriage prospects for women. In particular, it increased the likelihood of marriage for women and reduced female labor-force participation. The latter is a reflection of a tilt in household bargaining power toward women. Angrist (2002, p. 997) provides a quote from a Moroccan female immigrant saying "Every day I meet someone better. I am waiting for the best." Bronson and Mozzocco (2017) document, by analyzing nearly century of U.S. data, that higher cohort sizes are associated with higher marriage rates for *both* men and women. They find that variations in cohort sizes can explain a large variation in marriage rates since the 1930s.

Recent research suggests that the theoretical link between sex ratios and marriage can be complex. An excellent example is Knowles and Vandenbroucke (2019) who analyze the aftermath in France of World War I. They show that after World War I marriage rates increased for both men and women in France, despite a large drop in the sex ratio. They build a directed search model of marriage in which young and old men and women have different preferences for marriage. In particular, young men are less inclined to marry than either old men or young and old women. Due to bleak economic prospects, World War I was not a good time to marry and raise a family–see Vandenbroucke (2014) for an analysis of this. This impacted the marriage rates for older men more than younger ones, because the latter weren't as likely to marry. As a result the stock of single older men was affected more than for the stock of younger ones. Consequently, following the War the stock of marriageable men was high despite large casualties; furthermore, casualties were higher for younger men which compounded the situation.

Bronson and Mozzocco (2018) note that standard models of marriage would have a difficult time explaining how an increase in cohort size leads to a rise in the marriage rates for both men and women. Since women usually marry older men an increase in a cohort would reduce the ratio of marriageable men to women. A standard model would predict a fall in the marriage rate for women and a rise in the one for men. To overcome this prediction, they adapt the standard model so that men can undertake a pre-marital investment that increases their probability of meeting a potential spouse (as in Chiappori, Iyigun, and Weiss 2009). When the population is growing and men are in a relatively better position in the marriage market, they have lower incentives for pre-marital investment, which can result in lower marriage rates for them as well as women. Last, as discussed earlier, Caucutt, Guner, and Rauh (2018) analyze how the high incarceration (and unemployment) rates for black males has reduced the stock of marriageable men and has led to low marriage rates for blacks.

11 Appendix: Beers' Specification of Letters Patent

UNITED STATES PATENT OFFICE.

J. B. BEERS, OF ROCHESTER, NEW YORK.

PREVENTING CONCEPTION.

Specification of Letters Patent No. 4,729, dated August 28, 1846.

To all whom it may concern:

Be it known that I, JOHN B. BEERS, of the city of Rochester, in the county of Monroe and State of New York, have invented a new Instrument, called the "wife's protector," the design of which is to Prevent conception; and I do hereby declare that the following is a full and exact description.

It consists of six separate pieces, viz, hoop, band, joint, joint-pin, membranous covering, and handle.

It is constructed in the following manner: The hoop (A) is made of a piece of oval wire, formed into a ring about an inch and a half in diameter, and to this, is soldered the point (B), formed from a piece of hollow wire about $\frac{1}{2}$ an inch in length, which has two slots cut in it (C, C,) about $\frac{1}{4}$ of an inch apart, to receive the end of the handle (D, D,) which forms the other half of the hinge or joint. The center of this joint, from one slot to the other, is flattened at right angles with the hoop (A) to which it is attached.

The handle consists of one piece of metal, (gold alloyed with platina is to be preferred on account of its great elasticity, and not being liable to change color.) It should be about eight inches in length, and about $\frac{1}{16}$ of an inch in width, except the end that is crooked, which is left larger merely for ornament. The other end is about $\frac{3}{8}$ of an inch in width, and has two longitudinal slits extending $\frac{1}{4}$ of an inch from the end, and about $\frac{1}{16}$ of an inch from either edge, running parallel with the handle. The two outside planes are then formed into knuckles, to work like a hinge in the slots (C, C,) cut in the joint (B,). The center F is cut off even with the knuckles (D, D,) and is intended to rest upon the flat surface between the slots, and act as a spring, keeping the hoop while in use at right angles. The two are then united, and kept in their place by a joint-pin. The hoop is then covered with oil-silk, or some other thin membranous substance (E,) and held in its place by a metallic band, made to slip snugly over the hoop and thus securing the edges of the covering between them. The edges of the band are then to be burnished down smoothly; and lastly, the handle should be formed into shape, resembling the sectional view in the annexed drawing No. 2.

To use this instrument, the hoop is to be pressed down upon the handle by the thumb of the right hand, turning it up edgewise, and then introduced into the vagina, when, immediately after, having passed the sphincter, and the bones of the pelvis, it extends itself to its natural position, nearly at right angles with the rod or stem, and as it is farther introduced, the handle is to be turned downward $\frac{1}{4}$ of a circle. In this position the membrane on the hoop is made to completely cover the os uteri, thus entirely preventing the semen from entering the uterus, without which, (it is assumed) conception can not take place.

While the rod aforesaid lies along the lower side of the vagina, with a slight curve, to accommodate itself to the sphincter, and terminates in the angles above described, lying near the anus, and if properly adjusted, can not be felt by either party. After coition, when the instrument is being withdrawn the spring joint permits the extension of the hoop to nearly a parallel line with the rod accommodating itself to the shape and size of the vagina, and bringing the semen away with it.

What I claim as my invention, is—the particular combination of a covered hoop attached to a handle by a spring-joint as described and for the purposes above specified.

J. B. BEERS.

Witnesses:
DANIEL WOOD,
O. MORRIS.

12 Appendix: Theory

Proof of Proposition 5 (Mean and Median Ages of Marriage). Focus on the mean age of marriage, as given by (4). As can be deduced from

Table 1, the average age of marriage can be rewritten as

$$\frac{\sum_{i=1}^{j} i n_i}{\sum_{i=1}^{j} n_i} = \frac{\sum_{i=1}^{j} i s_{i-1}}{\sum_{i=1}^{j} s_{i-1}}, \text{ with } s_0 \equiv 1/\sigma.$$

Consider the distribution function given by $(\sum_{i=1}^{l} s_{i-1})/(\sum_{i=1}^{j} s_{i-1})$, for $0 \leq l \leq j$. Now, the odds of being around and single after $i-1$ periods are $s_{i-1} = [1-\mu+\mu W(w^*)]^{i-1}\sigma^{i-2}$. Therefore,

$$\frac{\sum_{i=1}^{l} s_{i-1}}{\sum_{i=1}^{j} s_{i-1}} = \frac{1-\phi^l}{1-\phi^j}, \text{ with } \phi \equiv [1-\mu+\mu W(w^*)]\sigma.$$

It is easy to check the righthand side is decreasing in w^*. This implies that the distribution function is stochastically increasing in w^* in the sense of first-order stochastic dominance; i.e., the odds of marrying by age l have decreased, while the odds of marrying after age l have increased. Trivially, the integer i is increasing in i. Consequently, by the theorem of first-order stochastic dominance [see Hadar and Russell (1971)] the average age of marriage must be increasing in w^* and hence π by Proposition 1.

The median age of marriage lies between l and $l+1$, where

$$\frac{\sum_{i=1}^{l} n_i}{\sum_{i=1}^{j} n_i} = \frac{\sum_{i=1}^{l} s_{i-1}}{\sum_{i=1}^{j} s_{i-1}} \leq 0.5 \leq \frac{\sum_{i=1}^{l+1} n_i}{\sum_{i=1}^{j} n_i} = \frac{\sum_{i=1}^{l+1} s_{i-1}}{\sum_{i=1}^{j} s_{i-1}}.$$

There are two cases to consider. The first case is where the median age of marriage moves out of the interval $[l, l+1]$. From the above analysis, the far righthand side is decreasing in w^*. This implies that the median age of marriage will increase in this situation. The second case is where the median age of marriage remains within the interval $[l, l+1]$. Here the median age of marriage is fixed at $(l+l+1)/2 = l.5$. So in the second case the median age of marriage is nondecreasing in the efficacy of contraception. ■

13 Appendix: Data Sources

13.1 Figures and Tables

- Figure 1 (fraction of the female population, 18-30, never married, 1880-2015): The data for 1880-1990 is from the *Historical Statistics of the*

United States: *Millennial Edition* (Table Aa614-683). The data for 2000-2015 is based on the authors' calculations from the U.S. Census Bureau's American Community Survey.

- Figure 1 (median age at first marriage, 1880-2018): United States Census Bureau, Historical Marital Status Tables, Table MS-2.

- Figure 2 (percentage of births to unmarried women, 1920-2017): For 1920 and 1930, see Cutright (1972, Table 1, p. 383); for the data between 1940 and 1999, see Ventura and Bachrach (2000, Table 1, p. 17); for 1999-2013, see Curtin, Ventura, and Martinez (2014); for 2014, 2015, 2016, and 2017, see National Vital Statistics Reports-Births: Final Data for the corresponding years.

- Figure 2 (non-marital births by age group per 1,000 women): Computed for the years 1940 to 1990 from *Historical Statistics of the United States* (Tables Aa614-683 and Ab264-305). For the years 2000 and 2007, the numbers are calculated using the birth rates for unmarried women, as given in the National Vital Statistics Reports, and the fraction of unmarried women, calculated using IPUMS USA.

- Figure 3 (premarital sex): For births cohorts pre-1900 to 1910-1919, the data is taken from Kinsey et al. (1953, Table 83, p. 339). The data for the later cohorts is from Wu, Martin, and England (2018, Table 3, p. 733).

- Figure 3 (number partners before marriage): The data for the birth cohorts from pre-1900 to 1910-1919 are from Kinsey et al. (1953, Table 78, p. 336). The numbers for the later cohorts are based on authors' calculations from the National Health and Social Life Survey (NHSLS). The numbers presume the woman had premarital sex with her future husband.

- Figure 4 (total fertility rate for white women): The numbers for 1800 to 1990 are from the *Historical Statistics of the United States* (Table Ab52-117). For the years 1991 to 2015, the data comes from Martin et al. (2017, Table 4, p. 21).

- Figure 4 (complementary cumulative distribution functions over children ever born): *Historical Statistics of the United States* (Table Ab498-535).

- Figure 12 (annual failure rate for contraception, 1900 to 2015-18): The annual failure rate data is provided in the last column of Table 6. The series is constructed from the data presented in Tables 5 and 6 on the uses and effectiveness of contraception.

- Table 4 (data targets): The fraction of women ever married by age for 1900 comes from the *Historical Statistics of the United States*: *Millennial Edition*, Table Aa614-683. For the year 2000 the data is from the U.S. Census Bureau's brief "Marital Status: 2000." The number of out-of-wedlock births per 1,000 unmarried women in 1920 derives from Cutright (1972, Table 1, p. 383). The corresponding number for 1998 is taken from the *Historical Statistics of the United States*: *Millennial Edition*, Table Ab264-305. The fractions of women who had premarital sex in 1900 are taken from Kinsey et al. (1953, Table 83, p. 339). For 2004 the numbers are in line with Wu, Martin, and England (2018, Table 3, p. 733). In particular, the fraction for age 25 is set equal to the fraction found for age 30, which is what the Wu, Martin, and England (2018) data strongly suggests. For 1900 the number of partners before marriage is for the before-1900 cohort listed in Kinsey et al (1953, Table 78, p. 336). The number for 2000 is based on authors' calculations from the 1992 National Health and Social Life Survey (NHSLS) and pertains to women born between 1963 and 1972.

- Tables 5 and 6 (use and effectiveness of contraception): See the detailed discussion below.

13.2 Contraceptive Use

Table 5 presents data on the use of contraception. For construction of the data before 1985, see Greenwood and Guner (2010). For 1985-2008, the numbers are taken from Mosher (2010, Table 3, p. 20). the data for 2010-18 are based on authors' calculations from the National Survey of Family Growth (waves from 2006-10 to 2015-17). The usage of multiple contraceptives by users was not reported until the 1995 NSFG. After that year, the sum across different methods is more than the total fraction who use any method. In Table 5 the percentage distribution across different methods is normalized to sum up to the total fraction who use any method. The "other" methods category includes the use of diaphragms, cervical caps, IUDs, vaginal spermi-

Contraceptive Use at First Premarital Intercourse, %					
Period	none	pill	condom	withdrawal	other
1900-59	61.4	-	9.42	11.19	17.99
1960-64	61.4	4.2	21.9	7.3	5.3
1965-69	54.2	8.6	24.0	9.5	3.7
1970-74	55.6	12.1	21.0	7.3	4.0
1975-79	53.5	12.8	22.0	7.5	4.2
1980-82	46.9	14.2	26.7	8.4	3.8
1983-88	34.6	12.1	41.8	8.9	2.6
1985-89	34.0	13.7	43.2	6.8	2.3
1990-94	30.3	15.4	47.3	4.5	2.5
1995-99	27.5	17.0	48.7	5.0	1.8
2000-04	24.2	17.0	53.4	2.5	2.9
2005-08	15.9	15.1	56.4	7.1	5.4
2010-14	19.4	21.9	51.3	3.3	4.2
2015-17	10.0	19.9	56.2	3.4	10.5

Table 5: The table shows contraception use at first premarital intercourse at various point in time. All numbers are expressed as percentages.

cides (such as foams, jellies, creams and sponges), the rhythm method, and injections and implants which were introduced in 1990s.

13.3 Contraceptive Effectiveness

Table 6 gives the annual failure rates for condoms, the pill, withdrawal, and other methods. For construction of the failure rates before 2000, see Greenwood and Guner (2010). For 2000-2008, the failure rates for no method, pill, condom and withdrawal are taken from Hatcher et al. (2004, Table 9-2, p. 226). For 2010-2014, the failure rates come from Hatcher et al. (2011, Table 3-2, p. 50). For 2015-2018, they derive from Hatcher et al. (2018, Table 3-2, p. 100).

Given the small number of people using other methods the results are not very sensitive to the assumption made regarding their effectiveness. In Greenwood and Guner (2003), the effectiveness of other methods is assumed to 20% until the end of 1980s and 10% afterwards, until around 2000. Given

Effectiveness of Contraception (annual failure rates), %						
Period	none	pill	condom	withdrawal	other	All (technology)
1900-59	85.0	-	45.0	59.2	50.0	72.05
1960-64	85.0	7.5	17.5	22.5	20.0	59.04
1965-69	85.0	7.5	17.5	22.5	20.0	53.79
1970-74	85.0	7.5	17.5	22.5	20.0	54.29
1975-79	85.0	7.5	17.5	22.5	20.0	52.81
1980-82	85.0	7.5	17.5	22.5	20.0	48.25
1983-88	85.0	3.4	11.0	20.5	20.0	36.76
1985-89	85.0	3.4	11.0	20.5	10.0	35.73
1990-94	85.0	5.5	14.5	20.5	10.0	34.63
1995-99	85.0	5.5	14.5	23.0	10.0	32.69
2000-04	85.0	8.0	15.0	27.0	5.0	30.76
2005-08	85.0	8.0	15.0	27.0	5.0	25.38
2010-14	85.0	9.0	9.0	22.0	5.0	28.63
2015-17	85.0	7.0	7.0	20.0	5.0	18.39

Table 6: The table shows the annual failure rates for contraception. All numbers are expressed as percentages.

the continuous improvements in many contraceptions, such as the IUD, diaphragm, and introduction of new ones. e.g. the patch, a failure rate of 5% is assumed for other methods since 2000.

The last column in 6 gives annual failure rate across all contraceptive technologies. This is the series plotted in Figure 12. To do this, an average is computed over the effectiveness of each method of birth control listed in Table 6. When doing this each practice is weighted by its yearly frequency of use shown in Table 5.

References

[1] Aiyagari, R., Greenwood, J., Guner, N. (2000). "On the State of the Union." *Journal of Political Economy* 108 (2), 213-244.

[2] Akerlof, G.,Yellen, J., Katz, M. (1996). “An Analysis of Out-of-Wedlock Childbearing in the United States.” *Quarterly Journal of Economics* 111 (2), 277–317.

[3] Albanesi, S., Olivetti, C. (2016). “Gender Roles and Medical Progress.” *Journal of Political Economy* 124 (3), 650–695.

[4] Angrist, J. (2002). “How Do Sex Ratios Affect Marriage and Labor Markets? Evidence from America’s Second Generation.” *Quarterly Journal of Economics* 117 (3), 997-1038.

[5] Becker, G.S. (1991). *A Treatise on the Family, Enlarged Edition*. Harvard University Press, Cambridge, MA.

[6] Becker, G.S. (1993). “Nobel Lecture: The Economic Way of Looking at Behavior.” *Journal of Political Economy* 101 (3), 385–409.

[7] Belsky, R. (1975). “Vaginal Contraceptives: A Time for Reappraisal?” *Population Reports* Series H, Number 3. George Washington University Medical Center.

[8] Bisin, A., Verdier, T. (2001). “The Economics of Cultural Transmission and the Dynamics of Preferences.” *Journal of Economic Theory* 97 (2), 298–319.

[9] Bronson, M.A., Mazzocco, M. (2017). “Cohort Size and the Marriage Market: Explaining Nearly a Century of Changes in U.S. Marriage Rates.” Unpublished Paper, Georgetown University.

[10] Bronson, M.A., Mazzocco, M. (2018). “Cohort Size and the Marriage Market: What Explains the Negative Relationship?” Unpublished Paper, Georgetown University.

[11] Browning, M., Chiappori, P.-A., Weiss, Y. (2014). *Economics of the Family.* Cambridge University Press, New York.

[12] Bullough, V.L. (Ed.). (2001). *Encyclopedia of Birth Control.* ABC-Clio, Inc., Santa Barbara.

[13] Carter, S.B. et al. (Eds). (2006). *Historical Statistics of the United States: Millennial Edition*. Cambridge University Press, New York.

[14] Caucutt, E.M., Cooley, T.F., Guner, N. (2013). "The Farm, the City, and the Emergence of Social Security." *Journal of Economic Growth* 18 (1), 1–32.

[15] Caucutt, E.M., Guner, N., Knowles, J.A. (2002). "Why Do Women Wait? Matching, Wage Inequality, and the Incentives for Fertility Delay." *Review of Economic Dynamics* 5 (4), 815–55.

[16] Caucutt, E.M., Guner, N., Rauh, C. (2018). "Is Marriage for White People? Incarceration, Unemployment, and the Racial Marriage Divide." Unpublished paper, Western University.

[17] Cavalcanti, T.V. de V., Kocharkov, G., Santos, C. (2019). "Family Planning and Development: Aggregate Effects of Contraceptive Use." Unpublished paper, University of Cambridge.

[18] Charles, K.K., Luoh, M.C. (2010). "Male Incarceration, the Marriage Market, and Female Outcomes." *The Review of Economics and Statistics* 92 (3), 614-627.

[19] Chiappori, P.-A., Iyigun, M., Weiss, Y. (2009). "Investment in Schooling and the Marriage Market." *American Economic Review* 99 (5), 1689-1713.

[20] Chiappori, P.-A., Salanié, B., Weiss, Y. (2017). "Partner Choice, Investment in Children, and the Marital College Premium." *American Economic Review* 107 (8), 2109–2167.

[21] Cole, H.L., Ohanian, L.E. (2004). "New Deal Policies and the Persistence of the Great Depression: A General Equilibrium Analysis." *Journal of Political Economy* 112 (4), 779-816.

[22] Cooley, T.F., Ohanian, L.E. (1997). "Postwar British Economic Growth and the Legacy of Keynes." *Journal of Political Economy* 105 (3), 439-472.

[23] Curtin, S.C., Ventura, S.J., Martinez, G.M. (2014). "Recent Declines in Nonmarital Childbearing in the United States." NCHS Data Brief, no. 162. National Center for Health Statistics. Hyattsville, MD.

[24] Cutright, P. (1972). "Illegitimacy in the United States: 1920-1968," In C.F. Robert, Parke, R. Jr. (Eds.), *Demographic and Social Aspects of Population Growth*, Vol. 1, U.S. Commission on Population Growth and the American Future, Government Printing Office, Washington, D.C., pp. 376-438.

[25] Doepke, M., Zilibotti, F. (2008). "Occupational Choice and the Spirit of Capitalism." *Quarterly Journal of Economics* 123 (2), 747–93.

[26] Edlund, L., Machado, C. (2015). "How the Other Half Lived: Marriage and Emancipation in the Age of the Pill." *European Economic Review* 80 (C), 295–309.

[27] Fernandez-Villaverde, J., Greenwood, J., Guner, N. (2014). "From Shame to Game in One Hundred Years: An Economic Model of the Rise in Premarital Sex and Its De-stigmatization." *Journal of the European Economic Association* 12 (1), 25–61.

[28] Galor, O., Klemp, M. (2019). "Human genealogy reveals a selective advantage to moderate fecundity." *Nature Ecology & Evolution* 3 (5), 853–857.

[29] Gershoni, N., Low, C. (2018a). "Older Yet Fairer: How Extended Reproductive Time Horizons Reshaped Marriage Patterns in Israel." Unpublished paper, The Wharton School, University of Pennsylvania.

[30] Gershoni, N., Low, C. (2018b). "The Impact of Extended Reproductive Time Horizons on Women's Human Capital Investments: Evidence from Israel's Expansion of Accessto IVF." Unpublished paper, The Wharton School, University of Pennsylvania.

[31] Goldin, C., Katz, L. (2002). "The Power of the Pill: Oral Contraceptives and Women's Career and Marriage Decisions." *Journal of Political Economy* 110 (4), 730–70.

[32] Greenwood, J. (2018) *Evolving Households: The Imprint of Technology on Life*. The MIT Press, Cambridge, MA.

[33] Greenwood, J., Guner, N. (2009). "Marriage and Divorce since World War II: Analyzing the Role of Technological Progress on the Formation of Households." In D. Acemoglu, Rogoff, K., Woodford, M.

(Eds.), *NBER Macroeconomics Annual 2008*. University of Chicago Press, Chicago, pp. 231–276.

[34] Greenwood, J., Guner, N. (2010). "Social Change: The Sexual Revolution." *International Economic Review* 51 (4), 893-923.

[35] Greenwood, J., Guner, N., Knowles, J.A. (2000). "Women on Welfare: A Macroeconomic Analysis." *American Economic Review* 90 (2), 383–388.

[36] Greenwood, J., Guner, N., Kocharkov, G., Santos, C. (2014). "Marry Your Like: Assortative Mating and Income Inequality." *American Economic Review Papers and Proceedings* 104 (5), 348–353.

[37] Greenwood, J., Guner, N., Kocharkov, G., Santos, C. (2016). "Technology and the Changing Family: A Unified Model of Marriage, Divorce, Educational Attainment, and Married Female Labor-Force Participation." *American Economic Journal: Macroeconomics* 8 (1), 1–41.

[38] Greenwood, J., Guner, N., Vandenbroucke, V. (2017). "Family Economics Writ Large." *Journal of Economic Literature* 55 (4), 1346-1434.

[39] Greenwood, J., Seshadri, A., Vandenbroucke, G. (2005). "The Baby Boom and Baby Bust." *American Economic Review* 95 (1), 183-207.

[40] Greenwood, J., Seshadri, A., Yorukoglu, M. (2005). "Engines of Liberation." *Review of Economic Studies* 72 (1), 109–33.

[41] Greenwood, J., Yorukoglu, M. (1997). "1974." *Carnegie-Rochester Conference Series on Public Policy* 46 (1), 49-95.

[42] Grimes, D.A., Ed. (2000). "Evolution and Revolution: The Past, Present, and Future of Contraception." *The Contraception Report* 10 (6), 15-30.

[43] Hadar, J., Russell, W.R. (1971). "Stochastic dominance and diversification." *Journal of Economic Theory* 3 (3), 288-305.

[44] Hansen, G.D., Prescott, E.C. (2002). "Malthus to Solow." *American Economic Review* 92 (4), 1205-1217.

[45] Hatcher, R.A. et al. (2004, 2011, 2018) *Contraceptive Technology*. Ardent Media, Inc. and Ayer Company Publishers 2018, New York.

[46] Himes, N.E. (1936). *Medical History of Contraception*. Williams and Wilkins Company, Baltimore.

[47] Kennes, J., Knowles, J.A. (2019). "Single Mothers and Shotgun Weddings." Unpublished paper, University of Aarhus.

[48] Kinsey, A.C., Pomeroy, W.B., Martin, C.E., Gebhard, P.H. (1953). *Sexual Behavior in the Human Female*. W.B. Saunders Company, Philadelphia, PA.

[49] Knowles, J.A., Vandenbroucke, G. (2019). "Fertility Shocks and Equilibrium Marriage-Rate Dynamics." *International Economic Review*, forthcoming.

[50] Kopecky, K.A. (2011). "The Trend in Retirement." *International Economic Review* 52 (2), 287-316.

[51] Kopecky, K.A., Suen, R.M.H. (2010). "A Quantitative Analysis of Suburbanization and the Diffusion of the Automobile." *International Economic Review* 51 (4), 1003-1037.

[52] Low, H., Meghir,C., Pistaferri, L., Voena, A. (2018). "Marriage, Labor Supply and the Dynamics of the Social Safety Net." National Bureau of Economic Research Working Paper 24356.

[53] Livi-Bacci, M. (2012). *A Concise History of World Population*. John Wiley & Sons, Ltd., Chichester, U.K.

[54] Martin, J.A., Hamilton, B.E., Osterman, M.J.K., Driscoll, A.K., Mathews, T.J. (2017). "Births: Final Data for 2015." National Vital Statistics Reports 66 (1). National Center for Health Statistics, Hyattsville, MD.

[55] Meyers, C.K. (2017). "The Power of Abortion Policy: Reexamining the Effects of Young Women's Access to Reproductive Control." *Journal of Political Economy* 125 (6), 2178-2224.

[56] Moffitt, R.A. (1992). "Incentive Effects of the U.S. Welfare System: A Review." *Journal of Economic Literature* 30 (1), 1-61.

[57] Moffitt, R.A., Phelan, B.J., Winkler, A.E. (2019). "Welfare Rules, Incentives, and Family Structure." *Journal of Human Resources*, forthcoming.

[58] Mosher, W.D., Bachrach, C.A. (1987). "First Premarital Contraceptive Use: United States, 1960-82." *Studies in Family Planning* 18 (2), 83-95.

[59] Mosher, W.D., Jones, J. (2010). *Use of Contraception in the United States: 1982–2008*. National Center for Health Statistics. Vital Health Stat 23 (29).

[60] Mosher, W.D., McNally, J.W. (1991). "Contraceptive Use at First Premarital Intercourse: United States, 1965-1988." *Family Planning Perspectives* 23 (3), 108-116.

[61] Ogburn, W.F., Nimkoff, M.F. (1955). *Technology and the Changing Family.* Houghton Mifflin, Boston, MA.

[62] Ohanian, L.E. (1997). "The Macroeconomic Effects of War Finance in the United States: World War II and the Korean War." *American Economic Review* 87 (1), 23-40.

[63] Olivetti, C. (2006). "Changes in Women's Hours of Market Work: The Role of Returns to Experience." *Review of Economic Dynamics* 9 (4), 557–587.

[64] Regalia, F., Rios-Rull, J.-V. (2001). "What Accounts for the Increase in the Number of Single Households?" Unpublished paper, University of Minnesota.

[65] Santos, C., Weiss, D. (2016). "Why Not Settle Down Already? A Quantitative Analysis of the Delay in Marriage." *International Economic Review*, 57 (2), 425-452.

[66] Schneider, D., Harknett, K., Stimpson, M. (2018). "Job Quality and the Educational Gradient in Entry into Marriage and Cohabitation." Unpublished paper, Washington Center for Equitable Growth.

[67] Shephard, A. (2019). Marriage Market Dynamics, Gender, and the Age Gap." Unpublished paper, University of Pennsylvania.

[68] Stevenson, B., Wolfers, J. (2007). "Marriage and Divorce: Changes and Their Driving Forces." *Journal of Economic Perspectives* 21 (2), 27–52.

[69] Tietze, C. (1963). "The Condom as a Contraceptive." *Advances in Sex Research* 1 (October), 88-102.

[70] Vandenbroucke, G. (2008). "The American Frontier: Technology versus Immigration." *Review of Economic Dynamics* 11 (2), 283–301.

[71] Vandenbroucke, G. (2014). "Fertility and Wars: The Case of World War I in France." *American Economic Journal: Macroeconomics* 6 (2), 108–136.

[72] Ventura, S.J., Bachrach, C. A. (2000). "Nonmarital Childbearing in the United States, 1940–99." National Vital Statistics Reports 48 (16). National Center for Health Statistics, Hyattsville, MD.

[73] Wilson, W.J., Neckerman, K.M. (1986). "Poverty and Family Structure: The Widening Gap between Evidence and Public Policy Issues." In Danziger, S.H., Weinberg, D.H. (Eds.), *Fighting Poverty: What Works and What Doesn't*, Harvard University Press, Cambridge, MA, pp. 232–259.

[74] Wu, L.L., Martin, S.P., England, P. (2018). "Reexamining trends in premarital sex in the United States." *Demographic Research* 38 (February), 727–736.