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Gender Roles and Medical Progress

Stefania Albanesi
Claudia Olivetti

Staff Report No. 720
March 2015

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Gender Roles and Medical Progress
Stefania Albanesi and Claudia Olivetti
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Abstract

Maternal mortality was the second-leading cause of death for women in childbearing years up until the mid-1930s in the United States. For each death, twenty times as many mothers were estimated to suffer pregnancy-related conditions, often leading to severe and prolonged disablement. Poor maternal health made it particularly hard for mothers to engage in market work. Between 1930 and 1960, there was a remarkable reduction in maternal mortality and morbidity, thanks to medical advances. We argue that these medical advances, by enabling women to reconcile work and motherhood, were essential for the joint rise in married women's labor force participation and fertility over this period. We also show that the diffusion of infant formula played an important auxiliary role.

Key words: maternal health, labor force participation

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1 Introduction

Up until the early decades of the twentieth century, poor maternal health made it difficult to reconcile motherhood and market work. Consider a typical woman born around 1900. She married at age 21 and gave birth to 2.6 children on average. Health risks in connection to pregnancy and childbirth were severe, leading to prolonged physical disability and, in the extreme, death. In 1920 one mother died every 125 live births.[1] For every death, twenty times as many mothers were estimated to suffer different degrees of disablement annually. Many maternal conditions had very long lasting or chronic effects on health, hindering women's ability to work well beyond their childbearing years. In addition, due to the lack of reliable alternatives, most infants were exclusively breast fed. A typical woman would then be nursing for a substantial amount of time during childbearing years. Not surprisingly given this burden, few married women worked.

Over the course of the twentieth century, married women's labor force participation increased dramatically, as shown in Figure 1. A large fraction of the increase occurred between 1930 and 1960. Approximately 12% of white married women aged 25 to 34 were in the labor force in 1930, and by 1960 their participation reached 26.7%. The rise in participation for women beyond their childbearing years was even greater, starting from 9% in 1930 and reaching 45.5% in 1970 for women aged 35-54. Over the same period fertility, which had been experiencing a secular decline until then, also rose substantially. The total fertility rate started from a through of 2.1 children in 1936 and reached a peak of 3.7 children circa 1960. This joint behavior is surprising, given that fertility and participation are typically negatively related.

Starting in the 1930s, there was a dramatic improvement in maternal health. Maternal mortality declined from 673 deaths per 100,000 live births in 1930 to 37.1 deaths per 100,000 live births in 1960 (Figure 2),[2] accompanied by a corresponding decline in the burden of pregnancy related conditions. At the same time, infant formula was developed in the mid-1920s and subsequently experienced a rapid diffusion. We argue that these developments, by enabling women to reconcile work and motherhood, were essential for the joint rise of married women's labor force participation and fertility over this period.

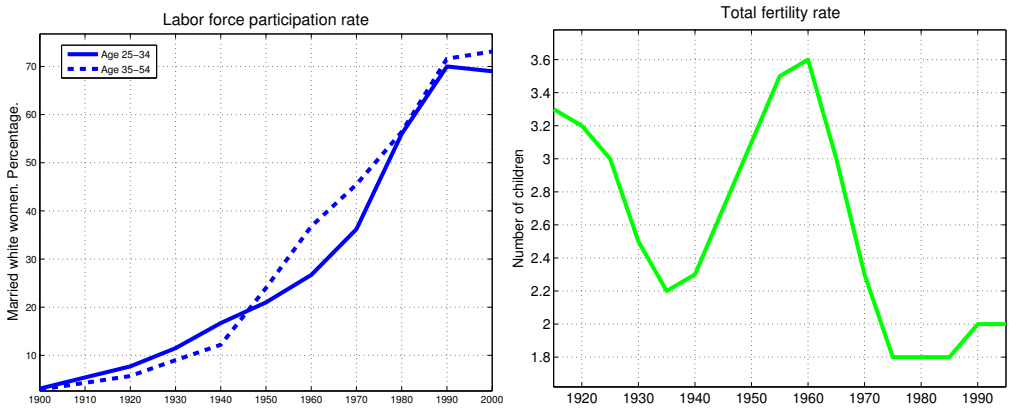
We use historical data to estimate the burden of maternal conditions based on the World Health Organization concept of disability adjusted life years (DALY), which quantifies the burden of a given disease from both mortality and morbidity. According to our estimates, the DALY associated with maternal conditions declined from 1.1 years per pregnancy in 1930 to 1 month per pregnancy in 1960.[3] To measure progress in infant feeding, we construct a measure of the time price for infant formula using newly collected data from historical newspapers. The time price declined by 82% between 1935 and 1960, remaining approximately constant thereafter. We

[1] The probability of survival to age 42 in 1920 was 75%. (Bureau of the Census, United States Abridged Life Tables 1919-1920). Thus, maternal causes account for 12% of the death hazard at age 42. The detailed list of sources and references for this section can be found in Appendix A.

[2] After 1960 maternal mortality continued to decline, albeit at a much slower pace, reaching 8.2 deaths per 100,000 live births in 1990.

[3] The rate of decline in the morbidity component of our DALY index is extrapolated from the maternal mortality and life expectancy series. See section 2.1.1 for details.

FIGURE 1: Married Women's Labor Force Participation and Fertility



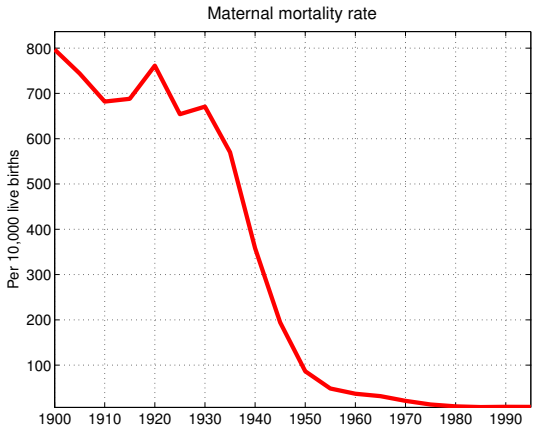
Notes. Left panel: Labor force participation of married white women aged 25 to 34 and age 35-54 (in percentages). Right panel: Total Fertility Rate (TFR) is the average number of live births a woman would have by the end of her childbearing years if she were subject, throughout her life, to the age-specific fertility rates observed in a given year. Its calculation assumes that there is no mortality. Data Sources: Labor force participation: Goldin (1990, Table 2.2), updated to 2000 based on decennial census IPUMS samples (Ruggles et al. 2010). Total Fertility Rate: *U.S. Cohort and Period Fertility Tables 1917-1980*, Institute of Child Health and Development (National Institutes of Health), and *National Vital Statistics Reports*, National Center for Health Statistics (several volumes). See Appendix A.1 and Appendix A.3 for further details on the construction of these series and data sources.

incorporate these measures of medical progress in a quantitative model to assess their role in accounting for the evolution of married women's labor force participation and fertility.

The quantitative analysis is based on a simple model of household labor supply with fertility choice. The economy is populated by married households who live for two periods, a childbearing stage and a post childbearing stage. Men are assumed to supply a fixed amount of labor in each period. Women choose participation in each period, and if they participate, they work for a fixed number of hours. Prior to childbearing, women can make a pre-marital investment in human capital, which increases their future productivity. Fertility is chosen in the first period of life, when births can occur. Births incur a time cost for mothers, that corresponds to the burden of maternal conditions as captured by the corresponding DALYs by age. In addition, children in their first year of life need to be nursed or bottle fed. Households choose whether to breast or bottle feed their children, which affects the time cost associated with infants. The monetary cost of infant formula appears in the household budget constraint. We also include the standard time cost of having children, corresponding to time required for play and child related chores, which varies by age.

Medical progress affects women's fertility and participation in the labor market. A decline in the burden of maternal conditions reduces the time cost of births for mothers, increasing the demand for fertility all else equal. The improvement in maternal health also affects participation. For given fertility, women's incentive to be in the workforce rises in both stages of life. This, in turn, increases their incentive to invest in human capital before marriage, raising their potential wage and further strengthening the rise in participation. The availability of infant formula also

FIGURE 2: Maternal Mortality



Notes: Maternal mortality rate per 100,000 live births. Data sources. 1900-1920: Appendix Table 5 in Loudon (1992); 1921-1990: Series Ab924, Haines (2006a).

plays a role. As its time price declines, women will resort to bottle feeding, especially if they intend to participate in the workforce and the demand for children is high. Given these properties, the model predicts that a decline in the burden of maternal conditions is associated with a joint rise in both fertility and participation, and an increase in the rate of bottle feeding.

To assess the quantitative relevance of this mechanism, we simulate the model, confronting subsequent cohorts of households with the estimated historical series for the burden of maternal conditions and the time price of infant formula, and other exogenously varying parameters, such as wages, husband's income and infant mortality. The model is calibrated to match US data on married women's participation, educational attainment, completed fertility, and breast feeding rates in 1930. We run several counterfactual experiments to evaluate the impact of each dimension of medical progress in isolation.

We find that medical progress is indeed a powerful force. The decline in the burden of maternal conditions can account for approximately 50% of the increase in both married women's labor force participation and fertility between 1930 and 1960. This result hinges on the critical role of medical progress in enabling married women's participation to rise contemporaneously with fertility. In fact, we show that the improvement in maternal health is essential to generate *any* rise in participation or fertility. Infant formula also plays an important role. Specifically, it appears to be most valuable when the burden of maternal conditions has declined enough so that both participation and the demand for children have started to rise.

Our model over predicts the growth in participation in 1940 and 1950 and under predicts its rise after 1960. Therefore, it also predicts a slower rise in fertility relative to the data, and fails to predict its sharp decline after 1960. This is not surprising since we abstract from a number of factors that affected participation. Factors depressing married women's participation in the early years include marriage bars and cultural aversion to women's market work. Forces that boosted participation in the later period include the diffusion of oral contraception, changes in the labor

market structure, as well as an attenuation of the cultural biases against working women. We show that if women's wages in the model are set so that participation is matched to the data in each simulation year, then the model is able to match the fast rise in fertility and its decline starting in the 1960s, suggesting that these additional factors, to the extent that they can be captured by latent changes in wages, play a role in explaining the joint behavior of participation and fertility in our framework.

Our analysis makes several contributions. It is the first to consider the impact of improved maternal health and infant feeding on the joint evolution of married women's labor force participation and fertility. From a theoretical standpoint, we isolate dimensions of medical progress that disproportionately affect women and incorporate them into a macroeconomic model of household behavior to quantify their impact. Our work relates in this dimension to Galor and Weil (1996), who examine the impact of the rise in jobs that require intellectual rather than physical skills, in which women have a comparative advantage. Other dimensions of technological progress, such as advances in home appliances (Greenwood, Seshadri and Yorugoklu, 2005, and Greenwood, Seshadri and Vanderbroucke, 2005) and the introduction of oral contraception (Goldin and Katz, 2002, and Bailey 2006) have also been linked to the rise in married women's participation and the evolution of fertility. Because these developments date to a later period,[4] they cannot account for the behavior of female participation and fertility as early as the 1930s.

We also make an empirical contribution by constructing a new economic measure of the burden of maternal conditions and its evolution over time in the United States. Our methodology is related to the literature on the effects of health on growth (Weil, 2007, and Ashraf, Lester, and Weil, 2008). In addition, consistent with the notion of technological progress embedded in new goods (Greenwood, Hercowitz and Krusell, 1997), we construct a measure of progress in infant feeding based on new historical data on the price of infant formula.

While in this paper we examine the quantitative impact of improvements in maternal health and infant feeding on married women's participation and fertility, Albanesi and Olivetti (2014) conduct an empirical study of the impact of maternal mortality reduction on fertility and education, exploiting its variation across US states and cohorts. The findings suggest that the growth in fertility was highest for US states and cohorts of women that experienced the greatest reduction in maternal mortality. Albanesi (2012) studies the link between fertility, human capital investment and maternal mortality reduction in a sample of over 30 countries during the twentieth century. She finds that sharp declines in maternal mortality are associated with a boom-bust pattern in fertility and an accelerated growth in women's schooling.

The paper is organized as follows. Section 2 briefly documents the medical advances in maternal health and documents the diffusion of infant formula. It also explains the construction of our measure of the burden of maternal conditions and of the time price of infant formula. Section 3 presents the analytical framework and describes our quantitative analysis. Section 4 concludes.

[4] See Albanesi (2008) for a discussion on this point.

2 Evidence on Medical Progress

The early decades of the 20th Century saw notable improvements in science and medicine that contributed to alleviate the health burden associated with women's maternal role. At the same time, advancements in nutritional science lead to the development of the first effective breast milk substitutes, which also contributed to reduce maternal time required for infant care. This section documents and quantifies these developments.

2.1 Advances in Maternal Health

The risk of temporary or permanent disability, and potentially death, associated with childbirth implied that mothers were subject to a very significant health toll until the early decades of the 20th century.[5] In the 1920s, the main cause of maternal death was septicemia (40%), followed by toxemia (27%), obstructed labor (10%), and hemorrhages (10%).[6] These conditions also led to the most debilitating symptoms in case of survival, such as neurological disorders, chronic anaemia and severe forms of perineal lacerations.

The rate of decline in maternal mortality over the course of the 20th century was highly uneven. Between 1900 and 1930, maternal mortality hovered around 700 deaths per hundred thousand live births. It then fell rather abruptly between the mid-1930s and the mid-1950s, and it stabilized around modern rates thereafter. This trend is in contrast to that of the overall mortality rate, and the mortality rates for major conditions, such as tuberculosis, which declined at a stable pace over the course of the 20th Century. This pattern can be seen in Table 1. Maternal causes, at 55 deaths per 100,000 female population in 1900, were the second largest cause of death for women after tuberculosis, which was the leading cause of death for both men and women at the time. Between 1900 and 1930, overall mortality for women declined by 37%, while maternal mortality declined by only 5.4% (at the same time mortality related to tuberculosis dropped by over 65%). As shown in Albanesi (2012), the continued high rate of maternal mortality until the early 1930s, in the face of declining mortalities for other conditions, was common to other advanced countries. The rate of maternal mortality in the US was particularly high, due mainly to the low standards of maternal care provided by birth attendants (Loudon, 1992b). However, over the next three decades, maternal mortality declined by 94%, while overall mortality declined by 22%.

The improvement in maternal health was the main force driving the change in female mortality rates between 1930 and 1960, when the maternal mortality rate was falling rapidly, but not before or after. The evolution of the gender gap in life expectancy supports this notion. As shown in the last row of Table 1, the female-male differential in adult life expectancy hovered around 2 years

[5] Much of this section is based on Loudon (1992) and Leavitt (1986), who provide historical accounts of maternal care and maternal mortality in the United States and other developed economies.

[6] Septicemia, also known as puerperal fever, is an illness that results from infection of the uterus during or after delivery. Toxemia is a severe form of pregnancy-induced hypertension. Death can occur as a result of damage to the kidneys or liver or from cerebral hemorrhage. In the past, the majority of deaths for this condition were due to eclampia, a condition characterized by the onset of convulsions. Obstetric hemorrhage typically occurs during or after delivery. It can be very sudden, unexpected and so copious that the patient can bleed to death. It occurs when the uterus is prevented from contracting fully and strongly. In the majority of cases, this is because the placenta is not expelled from the uterus.

between 1900 and 1930, and increased rapidly over the next thirty years, reaching 6 years in 1960. Pope (1992) shows that the systematic mortality sex differential in favor of females only emerged in the twentieth-century.[7] Additionally, Retherford (1972) shows that the decline in maternal mortality can account for the entire change in female-male differentials in mortality rates at age 20-39 between 1910 and 1965.

TABLE 1: Incidence of Maternal Mortality

	1900	1930	1960	1930-1900	1960-1930
	Death rates (100,000 population)			Percentage change	
All Causes					
Men	1791.1	1225.3	1104.5	-31.60%	-9.90%
Women	1646.9	1036.7	809.2	-37.10%	-21.90%
Tuberculosis					
Men	201	76.2	8.9	-62.10%	-88.30%
Women	187.8	65.9	3.3	-64.90%	-95%
Maternal Causes					
Women	55	52	3.4	-5.40%	-93.60%
	Deaths by cause (percentages)			Percentage change	
Maternal deaths as a percentage of:					
Female age 15-44 deaths	14.90%	10.60%	7%	-28.90%	-34%
All female deaths	3.20%	1.60%	0.10%	-50.00%	-93.80%
Tuberculosis as a percentage of:					
All deaths	11.30%	6.30%	0.70%	-44.20%	88.90%
	Life Expectancy at Age 20 (years)			Percentage change	
Female-male differential					
	2.0	2.5	6.1	25%	144%

Notes: This table reproduces Table 1 in Albanesi and Olivetti (2014). Top panel: Death rates per 100,000 population. Middle panel: Death rates by cause as a percentage of all deaths in the relevant population. Bottom panel: Female-male differential in life expectancy at age 20 (in years). Data sources. Mortality rates by gender and cause of death: 1900, 1930: Vital Statistics Rates in the United States 1900-1940, Table 15. 1960: Vital Statistics Rates in the United States 1940-1960, Table 63 and Table 1.M in VSUS 1960, Vol. 2a for puerperal causes. Life expectancy at age 20: Series Ab656-703, Haines (2006d).

Several factors contributed to the drastic decline in maternal mortality in the mid 1930s. The first is the introduction of sulfonamides, the first type of antibiotic. Jayachandran, Lleras-Muney and Smith (2010) estimate that sulfonamides were responsible for 24 to 36 percent of the decline in maternal mortality between 1937 and 1943.[8] The second factor is medicalization and hospitalization of childbirth. Physicians gradually entered the birth room starting in 1850. After 1935 births increasingly took place in hospitals. The fraction of births taking place in hospitals

[7] Women's life expectancy was lower than men's for much of the nineteenth century, when maternal mortality was very high. Based on census sex ratios between 1790 and 1950, the onset of women's advantage in mortality can be dated to the early decades of the twentieth century, with the largest gains in life expectancy occurring between 1940 and 1950. See Table 9.9 in Pope (1992).

[8] Maternal deaths due to sepsis, the cause of death which mainly benefited from sulfonamides, correspondingly experienced a sharp decline, from 275 per 100,000 live births in 1923 to 5.5 in 1955. Later, the diffusion of penicillin also contributed to the decline in maternal deaths from septicemia.

increased from 36.9% of all births in 1935 to 94.4% of births in 1955 (see Table 1 in Taffel, 1984). The intervention of physicians, at home and, especially, in the hospital, did not initially contribute to a reduction in maternal mortality. Exposure to the risk of infection and, especially, excessive operative interventions resulted in an initial rise in the rate of maternal deaths.[9] By the early 1930s, however, there were systematic efforts to improve and standardize obstetric practices in hospitals, and improve physician training. This led to the subsequent decline of maternal mortality rates in hospitals. The third factor is the availability of pre-natal care, starting in the late 1920s, which determined a decline in the incidence of deaths by toxemia. Finally, a number of additional scientific discoveries and advances in general medicine, such as the introduction of blood banking in 1936, also had a positive effect on maternal health.

To assess the economic impact of the high burden of pregnancy and childbirth until the 1930s, and its subsequent decline, we use data on on the incidence of maternal conditions and maternal mortality to construct an index of the burden of maternal conditions, quantified in units of time.

2.1.1 Burden of Maternal Conditions

The variety of possible debilitating conditions associated with pregnancy and childbirth implies that it is extremely difficult to provide a comprehensive assessment of the toll of childbearing on women's health and labor market performance. A small number of hospital based studies from the late 1920s offer detailed information on the incidence and duration of the most common ailments. We use this evidence in conjunction with the maternal mortality rate, and life expectancy to construct an indicator of the burden associated with maternal conditions. Our methodology adapts a standard approach that links improvements in health resulting in reductions in mortality to a decline in the burden of disease while alive.[10]

Our point of departure is the concept of Disability Adjusted Life Years (DALY) developed by the World Health Organization (WHO). This index quantifies the burden of a given disease from both mortality and morbidity. The DALY for a disease intends to measure the gap between the health status of the population due to that disease and an ideal situation in which the population lives to an advanced age free of disease and disability. The DALY is calculated by adding Years of Life Lost (YLL) due to premature mortality to Years Lost to Disability (YLD) for incident cases of the health condition. The YLL indicator is given by the product of the number of deaths for a given disease times standard life expectancy at the age at which the death occurs. The YLD indicator is obtained by multiplying incidence, duration and disability weight for each condition. The disability weight is an index of the degree of disablement ranging from 0 (perfect health) to 1 (death), for a given illness. In our application, we estimate YLL and YLD for pregnancy related conditions over the period of interest.

Years of Life Lost We calculate the YLL component of pregnancy using historical data on maternal mortality rates, live births, and female life expectancy for the average woman surviving to age 20. Column (1) to (4) in Table 2 report the data series used in our calculations. Column

[9] See Thomasson and Treber (2004) for an empirical analysis of this phenomenon.

[10] Weil (2007) offers an excellent discussion and review of this literature in economics.

TABLE 2: Calculations of Years of Life Lost (YLL) due to childbirth: 1920-1990

	(1)	(2)	(3)	(4)	(5)
	Life Expectancy at age 20 (additional years)	Maternal Mortality Rate (thousand live births)	Live Births (thousands)	Female Population (age 20 to 40)	YLL (years)
1920	46.5	7.80	2,950	15,077,142	0.0710
1930	48.5	6.73	2,618	17,397,683	0.0491
1940	51.4	3.76	2,559	19,134,218	0.0258
1950	54.6	0.833	3,632	21,129,755	0.0078
1960	56.2	0.371	4,258	20,723,409	0.0043
1970	57.4	0.215	3,731	23,281,991	0.0020
1980	59.4	0.092	3,612	29,860,157	0.0007
1990	60.3	0.082	4,158	32,068,706	0.0006

Notes: Column (5) is obtained as $[(1)\times(2)\times(3)]/(4)$. Data sources. Column (1): Series Ab656-703, Haines (2006d). Column (2): 1900-1920: Appendix Table 5 in Loudon (1992); 1921-1998: Series Ab924, Haines (2006a). Column (3): Series Ab11-30, Haines (2006b). Column (4) Series Aa287-364 (Haines, 2006c).

(5) shows the resulting YLL estimates in years, computed as the product of the additional years of life expected conditional on living to age 20 (column 1), the number of maternal deaths (the product of columns 2 and 3), divided by the female population at age 20-40 (column 4).

Not surprisingly, our estimates exhibit a declining trend that resembles the trend in maternal mortality, though the rate of decline of YLL also depends on changes in overall life expectancy. Based on our calculations, years of life lost to childbirth dropped by an order of magnitude between 1930 and 1960: from 2.4 weeks to 1 day.

Years Lost to Disability The YLD component of a disease is the product of its *incidence*, *duration* and WHO age-specific *disability weight*. The WHO reports disability weights for the consequences of the four main maternal conditions. These include infertility due to maternal sepsis, severe anemia due to maternal hemorrhage, neurological sequelae caused by hypertensive disorders of pregnancy and stress incontinence and recto-vaginal fistula resulting from obstructed labor (see Table A2 in Appendix A.6).[11] Some of these conditions are chronic and might have considerable impact on an individual's productive capacity. For example, neurological sequelae and recto-vaginal fistula are associated with a disability weight of approximately 0.40 (a value of 0 corresponds to perfect health). This is a relatively large value, considering that the disability weight for blindness is 0.60 and the one for AIDS is 0.51.

The WHO disability weights are the starting point in the construction of the YLD measure. We then collected the relevant historical data on the incidence and, for temporary conditions, the duration of these maternal conditions for the late 1920s to obtain the final estimate. The data come from obstetrical practices, such as that of the famous British obstetrician J.M. Munro Kerr. Based

[11] The WHO also includes a disability weight for the Sheehan syndrome, which is due to maternal hemorrhage. Since we could find no evidence of this condition in the historical accounts, we dropped it from our calculations.

on several hospital studies, Kerr (1933) documents an overall incidence of maternal morbidity of 12% of all live births for the second half of the 1920s. For sepsis, he estimates an incidence of 28.1 percent, or 3.4% of all live births.[12] However, since infertility (the only form of morbidity for this maternal cause in the WHO table) is unlikely to affect labor productivity, maternal sepsis does not enter in our estimate of YLD.[13] Kerr (1933) also documents that perineal lacerations from obstructed labor, the most debilitating and prevalent maternal condition, accounted for 67% of all cases of morbidity (or 8% of all live births). Based on information from his ward over the period 1928-1932, the duration of complaints ranged from seven months to 7-13 years, with an average duration of disablement of 55.67 months.[14] For the other conditions, we rely on Loudon (1992), who documents that 5.7% of all pregnancies would develop some form of illness due to maternal hemorrhage, while 10% would develop disablements as a consequence of hypertensive disorders.

Combining the historical information on incidence and duration with the WHO disability weights, we estimate that women would lose on average 1.17 years per pregnancy to disabilities related to maternal conditions.[15]

The per pregnancy burden of maternal conditions during childbearing years (DALY) is obtained as the sum of the YLL and YLD indices. It amounts to 1.24 year per pregnancy in 1920. Figure 3 plots the time series for the DALY estimates. This is obtained under the assumption that YLD declines at the same rate as maternal mortality. We make this assumption because there are no systematic time series data on the evolution of maternal morbidity.[16] The evidence that is available on the evolution of maternal conditions for the US broadly supports this notion. Comparing Kerr's (1933) study with estimates based on hospital discharge records for the United States by Franks et al. (1992), the postpartum pregnancy-related conditions requiring hospitalization dropped by 93% between the late 1920s and the mid 1980s, a magnitude similar to the drop in maternal mortality over the same period.[17] The YLL component varies over time also due to changes in

[12] See Kerr(1933), Table XLI.

[13] Even abstracting from the infertility consequences, maternal sepsis would lead to a short term disability for those who survived. For example, based on late 1920s data for Canada and Scotland, Loudon (1992) documents a duration of 18 to 19 days for this disablement (Table 4.3 and 4.4).

[14] See Appendix A.6 for the specifics of this calculation. The reliance on data from only one physician is potentially a limitation, as it may not be representative. On the one hand, it is plausible that a famed obstetrician such as Dr. Munro Kerr treated the most difficult cases, which would lead to overestimating the duration of these disablements. On the other hand, the obstetrician's ability was particularly important in the absence of proper training and standardized practices, which may imply that Dr. Kerr's patients experienced better outcomes than the broad population. Thus, the bias may go in either direction. We use frequency weights in our calculations on incidence and duration, so that the most exceptional cases do not overly weigh our estimate.

[15] This estimate is based on a 10-year childbearing period. The break down is 6.56 months for obstructed labor, 4.47 months for hypertensive disorders, and 1.04 months for maternal hemorrhage. The WHO also reports a disability weight of 0.22 for a healthy pregnancy, implying a YLD of 1.98 months, which is also included in our estimate. We refer the interested reader to Appendix A.6 for further details.

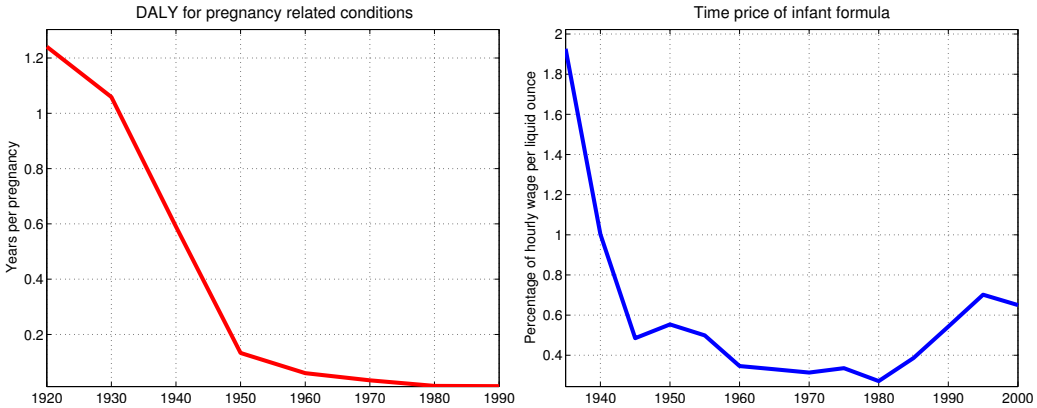
[16] This is true historically for the US and other developed economies and currently, for a cross-section of developing countries (see Wilcox and Marks, 1994, and Holly, Koblinsky and Mosley, 2000). The absence of data on morbidity is common to many diseases, not just maternal conditions. It is determined by the lack of generally accepted criteria for the measurement of morbidity, as well as significant obstacles to data collection. Therefore, the assumption of a common mortality/morbidity trend, although quite strong, is standard in the literature on the economic impact of disease eradication (Weil, 2007).

[17] See Albanesi and Olivetti (2014) for further discussion.

overall life expectancy, stemming from general medical progress. This implies that the mortality and morbidity component of the DALY decline at different rates.

As shown in figure 3, the estimated DALY per pregnancy declines sharply between 1930 and 1960, starting from approximately 1 year in 1930 and declining to 0.1 years in 1960. Thus, most of the decline in the burden of maternal conditions is attained in the course of three decades.

FIGURE 3: DALY per pregnancy (left) and time price of infant formula (right)



Notes. Left graph: Disability Adjusted Life Years (DALY) index for maternal condition for the period 1920 to 1990. Estimates are expressed in years. They are based on the assumption of a 10-year childbearing period. Right graph: Estimated time price of Similac. The time price is obtained by dividing the cost of 1 liquid ounce of Similac in a given year by the hourly wage in manufacturing in that year. See Appendix 2.1.1 and 2.2, respectively, for extensive details about the construction of these series.

2.2 Advances in Infant Feeding

Until the early decades of the 20th century, most infants were breast fed. The only two alternatives to breast milk were wet nurses or cows' milk. By the end of the 19th century, both these options were deemed inadequate.[18] The new discoveries in physiology, bacteriology and nutritional science in the second half of the 19th century revealed a connection between infant mortality, poor nutrition, and tainted water and milk supplies. A variety of public health initiatives with the purpose of reducing infant and child mortality from gastrointestinal diseases were undertaken in the major urban areas.[19] Efforts to develop a substitute for breast milk for infants whose mother had died spurred commercial and scientific interest in the development of infant formula, even as breast feeding was prescribed as the best practice. The most important innovation in infant feeding occurred in the early 1920s when two pediatricians created a water based infant formula that exactly reproduced the fat, protein and carbohydrate content in maternal milk. The first

[18] After a failed attempt to regulate wet nursing in the late 19th century United States, concerns about transmission of syphilis and other diseases led to its virtual disappearance by the mid-20th century (Golden, 1996).

[19] The establishment of the Children Bureau in 1912 advanced this agenda. By 1920, milk pasteurization had become the norm in most states, and by 1940 most metropolitan areas had developed sources of clean drinking water and sewage disposal systems (Wolfe, 2001). These developments were a necessary condition for the diffusion of infant formula.

two brands of so called "humanized" infant formula, SMA (simulated milk adapter) and Similac (similar to lactation) are still sold today. The humanized formulas were approved by the medical profession and were promoted as nutritionally equal to mother's milk and more convenient.[20]

2.2.1 Price of Similac

We measure progress in infant feeding with the decline in the opportunity cost of infant formula, or time price. To construct this measure, we collect data on the monetary cost of infant formula from historical advertisements from the Chicago Tribune, the Los Angeles Times and the Washington Post.[21] The advertisements provide information on price, quantity and type of formula in drugstore chains such as Walgreens and Stineway. The price observations refer to items on sale, hence, we interpret them as a lower bound. We combine monthly observations by city into a yearly aggregate series. The *time price* of infant formula is obtained by deflating the monetary price series by hourly wages in manufacturing from Margo (2006).

Figure 3 plots the estimated time price of Similac starting in 1935, the first sample year. We focus on Similac because it was the first commercially available humanized formula to become popular. In 1975, 52% of infants receiving formula were fed Similac (Fomon, 1975, Table III.)[22] The value of 2 for the time price in 1935 means that the cost of 1 liquid ounce of Similac corresponds to 2% of the hourly wage in manufacturing in that year, implying that a single average feeding would cost at least 40 minutes of work. This time price declined by an average of 6.6% per year between 1935 and 1960, and remained approximately constant thereafter.

The decline in the time price of formula determined a sharp reduction in the total cost of bottle feeding. The total amount of formula required to bottle feed a baby of median weight during the first year of life ranges between 92 pounds and 123 pounds based on our estimates. The corresponding yearly cost of bottle feeding an infant in 1936 thus ranged between $340 and $455, equivalent to 6 to 10% of average yearly income of white male full-time year-round salaried workers. By 1960, this cost had fallen to less than 1.5% of average yearly labor income. Section A.8 provides additional details on these calculations.

The diffusion of infant formula does not greatly reduce the time that must be devoted to infant feeding, though it potentially removes this burden from the mother, since other household members or child care providers can attend to this task. Combined with the reduced burden from maternal conditions, the advances in infant feeding arguably contributed to relax the constraints on married women's labor force participation. The rest of the analysis explores this hypothesis in the context of a quantitative model.

[20] The name Similac was proposed by Morris Fishbein, the editor of the Journal of the American Medical Association in the 1920s (Schuman, 2003). See also Packard and Vernal (1982) and Apple (1987) for a detailed account of the history of infant formula in the United States.

[21] This information is available from ProQuest Historical Newspapers Chicago Tribune (1849-1985), Los Angeles Times (1881-1985) and The Washington Post (1877 - 1990). We are grateful to Claudia Goldin for suggesting this data source. The details about the construction of the price series are discussed in the appendix.

[22] The uptake of SMA was very low. In 1975 it accounted for less than 12% of the market for infant formulas (Fomon, 1975). Enfamil, was launched in 1959.

3 Quantitative Analysis

To assess the economic relevance of the improvement in maternal health and the diffusion of infant formula, we develop a quantitative model of fertility and labor supply that captures these forces.

The economy is populated by overlapping generations of representative households, each comprised of two married adults, who experience three stages in life. In a pre-marital stage, women choose human capital investment, $e \in [0,1]$. Women's human capital investment before marriage affects their wages when married, as will be described below. The married phase of life is divided into two stages. The first, corresponding to age 25-34, is the one in which childbearing can take place. In the second, corresponding to age 35-54, children can be present, but no new births can occur. The presence of children is associated with a time cost in both stages of life. In stage 1 this time cost is given by three components. The first is the time required for generic childcare activities, such as feeding beyond infancy, child play, and household chores directly related to the care of children. The second corresponds to the health burden of pregnancy and childbirth, and the third corresponds to the time required for infant feeding. Households can choose the modality for infant feeding, which can be breast feeding or bottle feeding. In the second stage, we assume that all children are past infancy, therefore the third component is absent.

The household utility depends on consumption, women's total time burden and the number of children. Households choose the wife's pre-marital investment in human capital, denoted by e, fertility, specifically births, denoted with $b \geq 0$, wife's labor force participation in each stage, denoted with $p_t \in [0,1]$ for $t = 1, 2$, the fraction of infant feeding that is performed by administering bottled formula, denoted with $I_f \in [0,1]$, as well as joint consumption, $c_t \geq 0$, in each period. Husbands are assumed to participate fully in both stages of life, and their labor earnings, Y_t, are exogenously given in each stage. Children do not make any decisions.

The household utility function is:

$$U(e, b, p_1, p_2, I_f) = -\kappa(e) + \sum_{t=1,2} \beta_t \left[u(c_t) - v_t(n_t)\right] + g(sb),$$

with

$$n_1 = hp_1 + (\varphi_1 + s(\psi_1 + \upsilon))b - (\upsilon + \zeta)sbI_f + \xi(I_f)sb, \tag{1}$$

$$n_2 = hp_2 + (\varphi_2 + s\psi_2)b, \tag{2}$$

where $\kappa(\cdot)$ is an increasing and convex function, representing the utility cost of pre-marital human capital investment for the wife, $\beta_t \in (0,1)$ is the stage specific discount rate, $u(\cdot)$ is a strictly increasing and concave function representing the utility from consumption. The function $v_t(n)$ is the disutility of work for the wife, which can be age specific, where n_t is the combined time cost of labor supply and child bearing. The function $g(\cdot)$ represents the utility from children, it is increasing and strictly concave, and has, as an argument, the number of surviving children, sb, where b is the number of births and s the infant survival probability.[23]

The utility function is defined directly over women's total time cost of labor supply and child-

[23]The functions $\kappa(\cdot)$, $u(\cdot)$, $v(\cdot)$, and $g(\cdot)$ are also assumed to be continuous and twice continuously differentiable.

bearing, n_t, which reflects the following assumptions. Wives can choose participation $p_t \in [0,1]$ in each stage of life, and $h > 0$ is the fixed number of hours worked if they do participate. The parameters φ_t for $t = 1, 2$, represent the burden of pregnancy related conditions, which we take to correspond to the World Health Organization's DALY concept described in Section 2.1.1.[24] We allocate the Years Lost to Disability (YLD) component of the DALY across the two stages of life based on its distribution by age (as described in Appendix A.6), while we attribute the entire Years of Life Lost (YLL) component exclusively to the first stage of life, to capture the risk of death during childbirth.

We also incorporate the time cost of general childcare activities, ψ_t for $t = 1, 2$. This is specific to the stage of life, as it may depend on the children's age. In stage 1 only, there is an additional time requirement, υ, corresponding to infant feeding. Households can choose whether to nurse or bottle feed their infant children. The fraction of infant feeding that is performed via bottled formula is $I_f \in [0,1]$, so that if $I_f = 0$ children are exclusively breast fed, and if $I_f = 1$ they are exclusively bottle fed. The parameter $\zeta > 0$ captures non-convexities associated with breast feeding, namely the fact that it has to be done throughout the day on a fixed schedule. Therefore, the total time released by bottle feeding is $\upsilon + \zeta$, not just υ. The parameter ζ can be interpreted as the additional time available for market work if bottle feeding is used, in addition to the time saving υ. We also allow for a psychic cost of bottle feeding, corresponding to the function $\xi(I_f)$, which is increasing and convex, and captures the fact that the mother may experience a utility reward from breast feeding.[25] Since the time cost of these activities is only incurred for surviving children, we multiply b by the infant survival probability, denoted by $s \in [0,1]$. Instead, the burden of maternal conditions is incurred irrespective of the survival of the child.

Households solve the following problem:

$$max_{e \geq 0,\, b \geq 0, p_t \in [0,1], I_f \in [0,1]} U(e, b, p_1, p_2, I_f),$$

subject to

$$\frac{c_1}{1+r_1} + \frac{c_2}{1+r_2} \leq \frac{\bar{w}_1 h p_1 + Y_1}{1+r_1} + \frac{\bar{w}_2 h p_2 + Y_2}{1+r_2} - \frac{(q+\nu) w_1 I_f s b}{1+r_1}, \tag{3}$$

$$\bar{w}_t = (1 + \varepsilon_t e) w_t, \tag{4}$$

where equation 3 is the household's intertemporal budget constraint, with the stage specific real interest rate given by $r_t \geq 0$, while equation 4 represents women's wages at stage t. The total wage $\bar{w}_t$ is determined by the unskilled wage that prevails at age t, w_t, and by human capital investment, where $\varepsilon_t \geq 0$ is the return to human capital investment at stage t. Y_t denotes husband's labor

[24] This formulation abstracts from the risk of death, loading the average loss deriving from this risk on the time burden of pregnancy as captured by YLL. In a version of the model that explicitly incorporates mortality risk, the utility from stage 2, and possibly the utility from children, would only be enjoyed conditional on survival. The qualitative properties of such a version of the model would be identical to the current formulation.

[25] One possible interpretation of this cost is the presence of cultural norms favoring breast feeding, or the perceived additional health benefits to the child from breast feeding. We model this as a time cost but this is isomorphic to modeling a direct utility cost. All the properties of the model also hold without the psychic cost of bottle feeding. We introduce it to aid the calibration.

income at age t. The last term in the budget constraint represents the financial cost associated with bottle feeding. This includes the cost of purchasing formula, which is qw_1, where q represents the time price of formula multiplied by the total number of yearly ounces required for feeding, as well as the opportunity cost of time associated with bottle feeding, which are evaluated at the unskilled wage.

Households have perfect foresight and take as given the entire path of the health parameters φ_t, s, the child care time ψ_t, as well as the interest rate r_t, baseline wages w_t, the returns to human capital investment ε_t, and the time cost of baby formula, q.

We will assume $\frac{1}{1+r_t} = \beta_t$, so that at the optimum $c_1 = c_2$. The remaining first order conditions for this problem at an interior optimum are:

$$-\kappa'(e) + u'(c_t) \sum_{t=1,2} \beta_t w_t \varepsilon_t h p_t = 0, \tag{5}$$

$$u'(c_t) W_t - v'(n_t) = 0, \tag{6}$$

for $t = 1, 2$,

$$-\beta_1 u'(c_1)(q+\nu)w_1 + \beta_1 v'(n_1)\left((\nu+\zeta) - \xi'(I_f)\right) = 0, \tag{7}$$

$$-\beta_1 v'(n_1)\xi(I_f)s - \sum_{t=1,2} \beta_t v'(n_t)(\varphi_t + s\psi_t + \upsilon) + sg'(sb) = 0, \tag{8}$$

in addition to the budget constraint holding with equality.

These equations clearly spell out the main mechanisms in the model. From equation 5, the first order necessary condition for human capital investment, the marginal benefit of human capital investment rises with participation in both stages of life (p_t), as well as with the returns to this investment (ε_t) and unskilled wages (w_t).

A higher burden of maternal conditions or a higher time requirement for childcare (corresponding to n_t) increases the marginal cost of market work for wives and reduces desired participation, from equation 6, the intratemporal Euler equation.

Equation 7 is the first order necessary condition for the infant feeding choice. Clearly, lower values of the time price of infant formula (q) reduce the marginal cost associated with bottle feeding (the first term of the equation), whereas higher non-convexities (ζ) or lower psychic cost of bottle feeding increase the marginal benefit of bottle feeding (the second term). Also, note that births do not enter this condition directly. However, when births are high, the marginal disutility of labor is also high, which increases the marginal benefit from bottle feeding.

Finally, equation 8 is the first order necessary condition for births, where equation 6 has been used to simplify. The first term of this expression is zero if children are exclusively breast fed, since it depends on the psychic cost of bottle feeding. The second and third term capture the conventional effects typically found in fertility choice models. The second term illustrates that a higher burden of maternal conditions increases the marginal utility cost of births and reduces

desired fertility. The second term also implies that a rise in non-labor income will tend to increase fertility for parameterizations, such as we will consider, for which participation depends negatively on non-labor income. The third term is the marginal benefit of children, which increases with the survival probability and decreases with the number of children.

Given these qualitative properties of the model, the response to a decline in the burden of maternal conditions is unambiguous, with participation and fertility both rising, for given human capital. This response is unique to our model, as other factors that can increase participation would increase the marginal cost of children and reduce fertility. The availability of infant formula also plays a role. As its time price declines, women will resort to bottle feeding, especially if they intend to participate in the workforce and the demand for children is high. This further relaxes the trade-off between participation and fertility, leading to a joint rise in fertility, participation, and the rate of bottle feeding.

Rising participation increases women's incentive to invest in human capital, raising women's potential wage and further strengthening the rise in participation. If the returns to human capital investment are sufficiently high and fertility is already high, a decline in the burden of maternal health may induce participation to rise enough that fertility actually declines. But for empirically relevant parameters, at the low levels of fertility prevailing in the 1930s in the US, the positive direct effect on fertility will prevail.

To examine the quantitative relevance of the mechanism embedded in our model, we calibrate the model to 1930 and then simulate it over time, feeding in the time series for the exogenous forces, including the burden of maternal conditions φ_t, the time cost of infant formula q_t, baseline wages w_t, the returns to human capital investment ε_t, non-labor income Y_t for $t = 1, 2$, and the infant mortality rate. This exercise allows us to assess the contribution of improved maternal health and the availability of infant formula on labor force participation and the path of fertility, jointly with the secular changes in wages, the returns to human capital and non-labor income. We also conduct several counterfactuals designed to capture the contribution of each force in isolation. We find that the improvement in maternal health is essential for the joint rise in married women's participation and fertility between 1930 and 1960. The availability of infant formula sizably amplifies this effect.

Our framework assumes a representative household in each cohort. Allowing for heterogeneity, the model would predict a differential response across groups. As is well known, infant mortality was higher for low income households (Meckel, 1990). This reduces the benefit of increasing births for those households, and dampens the response of fertility to a decline in the burden of pregnancy. Additionally, educated women have a higher opportunity costs of births, which would lower their fertility relative to women with less education. But this implies that children have a higher marginal value for educated women, which would lead to a greater rise in births for these women in response to a decline in the burden of maternal conditions. These predictions of the model are consistent with the response of fertility across US states with different income and by mother's education, as shown in Albanesi and Olivetti (2014). We abstract from heterogeneity in this formulation to focus on the aggregate implications of the decline in the burden of maternal conditions and the availability of infant formula.[26]

[26] For a version of the model with heterogeneous households see Albanesi and Olivetti (2009).

3.1 Calibration

We make the following assumptions on functional forms. The utility cost of human capital investment is:

$$\kappa(e) = \gamma_0 \frac{e^{1-\gamma}}{1-\gamma},$$

with $\gamma_0 > 0$ and $\gamma < 0$. The utility from consumption is CRRA, with intertemporal elasticity of substitution $1/\sigma$, for $\sigma \geq 0$. The disutility cost of labor is:

$$v_t(n) = \mu_{0,t} \frac{n^{1-\mu}}{1-\mu},$$

where the scaling factor $\mu_{0,t}$ is age specific to capture variation in the costs of time by age. The utility from children is:

$$g(sb) = \rho_0 \frac{(sb)^{1-\rho}}{1-\rho},$$

where $\rho_0 \geq 0$ and $\rho \geq 0$. The psychic cost of bottle feeding is:

$$\xi(I_f) = \delta_0 \frac{I_f^{(1-\delta)}}{1-\delta} \geq 0,$$

where $\delta_0 \geq 0$ and $\delta < 0$.

We calibrate the model to 1930. We set yearly real interest rate to 5%. We set the maternal health burden parameters φ_t to correspond to the DALYs for pregnancy related conditions estimated in Section 2.1.1, distributed according to age. Stage 1 is the childbearing stage, corresponding to age 25-34, therefore, φ_1 includes both the age specific YLD and YLL. Since no births can occur in the post-childbearing stage, corresponding to age 35-54, φ_2 only captures YLD after fertility is completed. We use WHO age specific disability weights to estimate φ_1 and φ_2 in Appendix A.6.

The youth survival probability is a function of infant and child mortality. Child mortality decreased starkly during the second half of the 19th century and early in the 20th century. By the early 1920s, most youth mortality was accounted for by infant mortality. For this reason, we set the youth survival probability, s, to correspond to the infant mortality rate, which was approximately 6 per 100 live births in 1930.

The variable h, which corresponds to the fixed work time if participation is positive, is set to correspond to 8 work hours per day plus 2 hours of commuting/ preparation for 50 weeks per year and is then expressed as a fraction of a notional time endowment, given by 16 hours of wake time per day, for 7 days a week, for 52 weeks a year. All the other time use variables are expressed in the same unit.

Our estimate of υ, the time required for infant feeding, is derived from historical time use evidence in Brossard (1926), who reports that infant feeding added 15 hours of home production a week.[27] The parameter ζ captures non-convexities in breast feeding, specifically, the fact that

[27] This is a lower bound. Brossard's study of professional women in the Washington D.C. area in the mid-1920s

feedings must be performed on a fixed schedule that interferes with most market activities. For this reason, we set $\zeta = h$ so that, when bottle feeding is adopted, the corresponding time becomes available for market activities.

For general child care time, ψ_t, we follow the estimates of Zick and Bryant (1996). As described in Appendix A.4, we construct estimates of ψ_t using data on mother's time required for child care based on the age of the child. The resulting estimates suggest that on average during the childbearing stage of life mothers spent 19.07 hours per week on childcare, whereas for the post childbearing phase they spent 6.71 hours per week. The notable difference between these values depends on the fact that the time required for active childcare falls steeply with the age of the child, and average age of children is much higher in the second stage.[28]

We estimate weekly earnings and returns to human capital by age based on publicly available Census IPUMS data (Ruggles et al. 2010) for 1940 to 2000, and we project our estimates back to 1930. The estimates are selection adjusted using the standard two-step Heckman correction procedure (see Appendix A.2 for details). We define as "skilled" women who completed at least 12 years of schooling, and as "unskilled" those with fewer than 12 years of schooling. Based on the same data we also estimate non-labor income at each stage of life using total annual labor earnings of white married men aged 25-34 and 35-54, respectively, which correspond to Y_1 and Y_2 in the model.

We now turn to the utility parameters. We set $\sigma = 1.2$ consistent with standard estimates. We set μ to match a Frisch elasticity at the intensive margin of 0.3 consistent with empirical evidence based on micro level data (see, for example, Blundell and MaCurdy, 1999).[29]

We set the curvature parameters for the cost of human capital investment, γ, the psychic cost of bottle feeding, δ, and the utility from children, ρ, to match the 1930 to 1960 change in human capital, breast feeding rates and fertility, respectively, observed in the data.

The remaining parameters, γ_0, $\mu_{0,t}$ for $t = 1, 2$, δ_0 and ρ_0, are set to match human capital investment for women aged 25-34 (that is, the fraction with at least twelve years of schooling), labor force participation rates by age, breast feeding rates and fertility in 1930. We take the labor force participation statistics from Goldin (1990). We adapt it to the model age groupings as described in Appendix A.3. The breast feeding rate is the fraction of babies that are breast fed at 6 months. This time series is obtained using a variety of data sources which are listed in Appendix A.7. We take b to correspond to completed fertility, which we measure with children ever born at age 35-54 from the Census IPUMS.[30]

The calibrated values of the parameters are presented in Table 3.

suggests that an infant would add from a minimum of 15 hours per week for feeding and cleaning to a maximum of 31 hours also including bathing, dressing, changing and pacifying. We are grateful to Valerie Ramey for pointing us to this source.

[28]This estimate might seem low by modern standards (see, for example, Guryan, Hilt, Kearney, 2008), though it is consistent with the historical upward trend in parental time spent in childcare activities. For example, Bryant (1996) documents an increase in childcare time between 1925 and 1968, while Ramey and Ramey (2010) document a further increase since the early 1990s.

[29]This may seem on the low side but, as also shown in Rogerson and Wallenius (2009), the corresponding extensive margin elasticity predicted by the model is considerably larger and consistent with macro estimates.

[30]These are defined by the Census as the number of live births by all fathers, whether or not the children were still living; they were to exclude stillbirths, adopted children, and stepchildren.

TABLE 3: Calibrated parameters

γ	-8	γ_0	214.6241
σ	1.2	h	0.4293
μ	-33.9854	$\mu_{0,1}$	$2.1248e+36$
Frisch elasticity	0.3	$\mu_{0,2}$	$2.7276e+40$
δ_0	0.5790	δ	-5
ρ_0	22.5	ρ	5
ψ_1, ψ_2	0.0134, 0.0599	ν	0.1435

3.2 Simulations

Our model features three exogenous sources of change: the improvement in maternal health, the decline in the time price of infant formula, the secular rise in wages as well as the increase in returns to human capital investment. In addition, non-labor income increases and infant mortality declines over time.[31]

We are interested in identifying the role of each of these forces, as well as their combined effect, on women's labor force participation and fertility. To this end, we first simulate the model feeding in the cohort-specific time series for these exogenous processes jointly, and then analyze the impact of each force in isolation.

Our estimates of progress in maternal health are the cohort specific DALYs described in Section 2.1.1 and Appendix A.6. There are two relevant values of the DALY for each cohort. The one they experience at the time of their human capital investment, which informs their expectations, and the one that they actually face during their childbearing years. These will differ given the rapid rate of improvement in maternal health over this time period. Thus we use an average of the perceived and realized DALY for each cohort to proxy for the overall exposure to this burden.[32] The time series for the DALYs used to construct the estimates of φ_t for the simulation exercise takes into account that the number of pregnancies is greater than the number of live births, due to the fetal death rate.[33]

Figure 4 plots these model specific DALYs, as well as the time series for unskilled wages, returns to human capital and non-labor income that we use in the simulation. For the time price of infant formula, q, we use the estimates described in Section 2.2, as plotted in figure 3. The infant mortality rate also declines smoothly over the simulation period, and we use the historical

[31] In a fully aggregated model, long run TFP growth would translate into secular growth in real wages. However, this growth need not be reflected equally across all demographic groups. Specifically, we find that while the wages for white married women aged 25-34 do exhibit moderate secular growth, the wages for those aged 35-54 actually decline, a feature due to selection. Instead, non-labor income, which corresponds to husbands' labor earnings, does capture some of the secular growth in productivity in our model.

[32] This assumption is based on the empirical findings in Albanesi and Olivetti (2014), suggesting that both the maternal mortality rate at age 5-15 and the maternal mortality rate experienced during the childbearing years are important determinant of women's fertility and labor force participation decisions. In the first case this occurs indirectly through their education decisions.

[33] The fetal death rates exhibits a downward trend in our simulation period, driven by improved pre-natal care (O'Dowd and Phillipp, 1994) and a fall in the incidence of obstructed labor. This reduces the number of pregnancies per live birth.

infant mortality rate in each year for the simulation.[34]

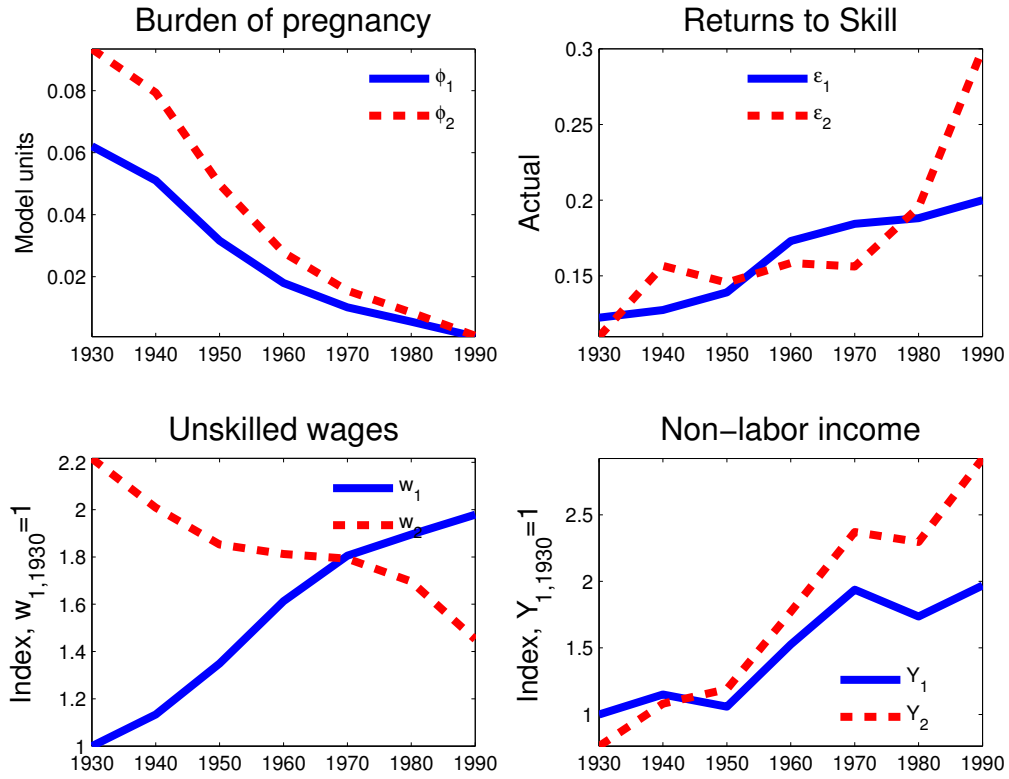


FIGURE 4: Exogenous forces in the model

Notes. Burden of pregnancy: Several data sources, see section 2.1.1 and section A.6 for details. Returns to skill, unskilled wages and non-labor income: Authors calculations based on the 1940-1990 decennial census IPUMS samples (Ruggles et al. 2010). See Appendix A.2 for further details.

Figure 5 presents the baseline simulation results. In each panel, the dotted blue line corresponds to the data while the solid red line corresponds to the model outcome. The variables p_1 and p_2 correspond to participation of married women at age 25-34 and 35-54, respectively, while completed fertility b corresponds to children ever born at age 35-54. Participation at age 25-34 rises from 12% in 1930 to 28% in 1960, and further accelerates in subsequent years in the data. Participation at age 35-54 grows at a faster pace over that period, starting from 9% in 1930 and reaching 37% in 1960, and then continues to rise at a slower pace subsequently. Fertility rises from 2.0 children in 1930 to 3.1 children in 1960, and drops sharply in later years.

The model can clearly capture the simultaneous increase in labor force participation and fertility between 1930 and 1960. In the model, participation in stage 1 grows from 12% in 1930 to 23% in 1950 and then drops to 17% in 1960 as fertility peaks. In the data, participation at age 25-34 monotonically increases throughout the period. Fertility grows from 2 in 1930 to 2.75 in

[34]The infant mortality rate was approximately 100 deaths per thousand live birth in 1900 and declined to 71 deaths per thousand live births in 1930. It had declined to 26 deaths per thousand live births in 1960 (Haines, 2006a).

1960 in the model, whereas it peaks at 3.1 in 1960 in the data. The model also generates a strong growth in labor force participation at age 35-54 and human capital investment between 1930 and 1960. The model predicts that the growth in participation at age 35-54 is larger than at age 25-34, consistent with the data. As shown in Table 5, the baseline model can account for approximately 40% of the 1930-1960 change in participation at age 25-34 in data, and for approximately 61% and 55% of the growth in participation at age 35-54 and fertility, respectively. The growth in women's human capital predicted by the model between 1930 and 1960 is approximately equal to the growth in the data. The simulation also generates the decline in breast feeding rates, though, mirroring the behavior of labor force participation in stage 1, it slightly overestimates the drop between 1930 and 1950, and under-predicts its decline between 1950 and 1980.

The model cannot predict the continued rapid growth in labor force participation and educational attainment of married women post-1960, and it also cannot replicate the associated large decline in fertility. This is not surprising given that the effects of our source of medical progress are largely exhausted by 1960, and the improvements in maternal health are permanent. Other factors, such as the contraceptive pill, the change in the wage structure and changing cultural norms played an important role for women's participation, education and fertility choices. We will return to this in Section 3.5. However, the model is able to capture the unique role of improvements in maternal health and infant feeding in explaining the *joint* rise of both fertility and participation between 1930 and 1960, in contrast to other theories of the baby boom.[35]

The improvement in maternal health and infant formula have a direct effect on participation and fertility in the model, though the corresponding reduction in the time burden of pregnancy and infant care. They also have an *indirect* effect, since by increasing participation, they increase the returns to human capital investment. The resulting rise in this investment further increases participation, though it increases the opportunity cost of births, for given maternal health burden and price of infant formula. To assess the strength of this amplification mechanism on participation and its corresponding impact on the response of fertility, we simulate a version of the model in which human capital investment is fixed at its 1930 value throughout the simulation.

Table 4 reports the value of participation and fertility in the model with fixed human capital and the percent difference between the baseline model and the model with fixed human capital. The amplification mechanism associated with the choice of human capital investment has the largest effect on participation, particularly in the second stage of life. Comparing across models, we find that, in 1940, p_1 is 8 percent larger in the baseline than in the version of the model with fixed human capital, while p_2 is 21 percent larger. By 1960, this differential grows to 36 and 42 percent, respectively. Fertility is also higher in the baseline model than in the version with fixed e, despite the fact that participation grows more. This outcome is enabled by the fact that women compensate the higher participation rate in the baseline model with higher bottle feeding rates.

[35] For example, Doepke, Hazan and Maoz (2014) argue that World War II is responsible for the baby boom, since young women were shut out of the labor market after the war by older women who had entered during the war. However, as we show, the participation of mothers increased over this time period.

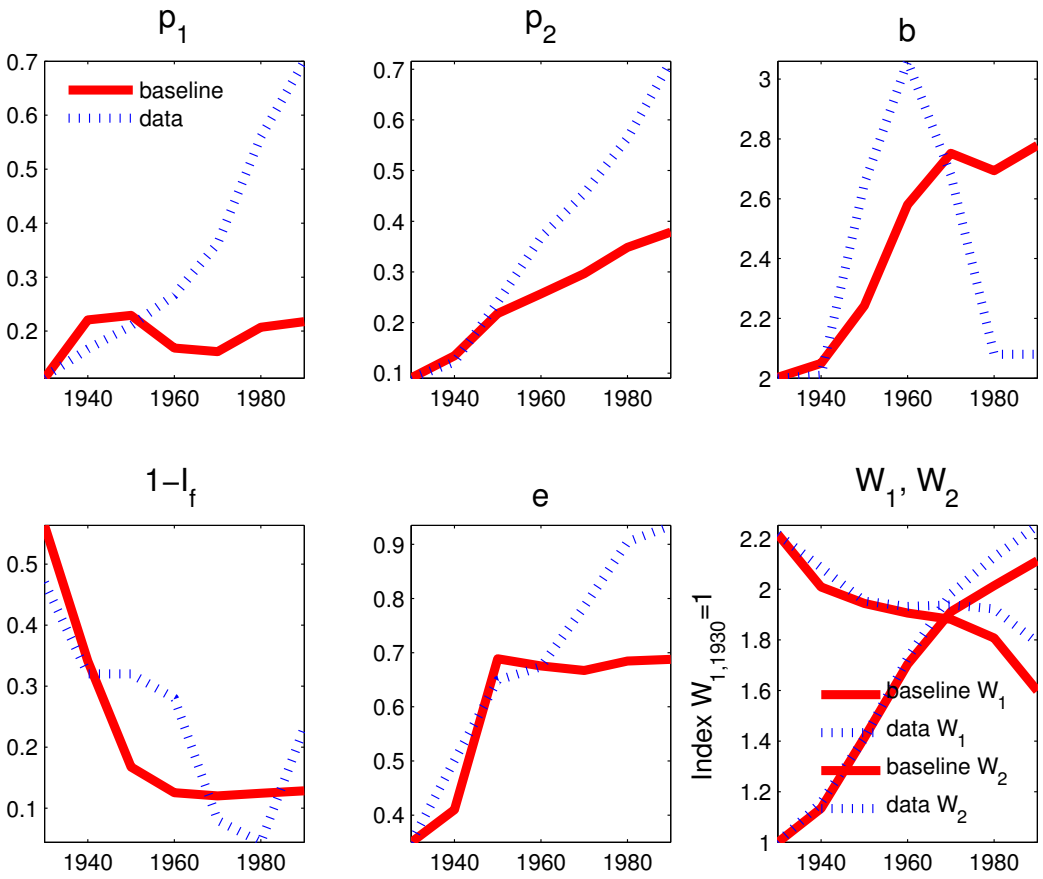


FIGURE 5: Baseline simulation

Notes: p_1 is labor force participation at age 25-34, p_2 labor force participation at age 35-54, b is children ever born at age 35-54, I_f is the bottle feeding rate, e is human capital investment, corresponding to having completed twelve years of schooling. w_1 and w_2 are unskilled wages at stage 1 and 2. The *baseline* version of the simulations allows for time variation in all exogenous variables in the model.
Data Sources: Labor force participation of white married women aged 25-34 (p_1) and 35-54 (p_2): Goldin (1990, Table 2.2), updated to 1990 based on decennial census IPUMS samples (Ruggles et al. 2010). Total Fertility Rate: *U.S. Cohort and Period Fertility Tables 1917-1980*, Institute of Child Health and Development (National Institutes of Health), and *National Vital Statistics Reports*, National Center for Health Statistics (several volumes). Bottle feeding rate: Apple (1987), Table 9.1, Hirschman and Butler (1981) and Ryan et al. (2002). Education and earnings: 1940-1990 decennial census IPUMS samples (Ruggles et al. 2010). See Appendix A.3, A.1, A.7 and A.2 for further details on the construction of these series.

3.3 Impact of Medical Progress

To analyze the contribution of each force of medical progress in isolation, we now run several counterfactuals. The results of this exercise are reported in figure 6 and in Table 5.

Figure 6 reports three versions of the simulation. The solid line is the baseline discussed above. The dashed line corresponds to a version of the model with no improvement in maternal health. The dash-dotted line corresponds to a simulation with no decline in the time price of infant formula. The dotted line corresponds to the data. For brevity, we focus on participation in

TABLE 4: Comparison of Baseline to Model with Fixed Human Capital

	p_1		p_2		b	
year	Fixed e	Baseline-fixed e	Fixed e	Baseline-fixed e	Fixed e	Baseline-fixed e
1930	12%	0	9%	0	2.0	0
1940	21%	8	11%	21	2.0	1
1950	19%	18	15%	47	2.2	4
1960	12%	38	16%	61	2.5	4
1970	12%	36	21%	42	2.7	3

Notes: p_1 is labor force participation at age 25-34, p_2 labor force participation at age 35-54, b is children ever born at age 35-54. In the fixed e version of the model, human capital is constant at its 1930 value. For Baseline-fixed e columns, entries in the table report the percent difference between the baseline and the model with fixed human capital.

the first stage of life and fertility.

In the absence of any improvement in maternal health, the model does not predict any sustained rise in participation or fertility.[36] While in the baseline version of the model, participation at stage 1 rises by 6 percentage points between 1930 and 1960, in the simulation without improvement in maternal health it declines by 7 percentage points over this period (see Table 5). This outcome is driven by negative income effects stemming from the growth of non-labor income (husbands' labor earnings), which reduces women's incentive to participate. Fertility rises by 0.2 children without improvements in maternal health between 1930 and 1960, only a third of the rise predicted by the baseline model. The growth in fertility absent improvements in maternal health is also due to an income effect on the demand for children. Because of the low demand for children, progress in infant formula cannot generate by itself the joint rise in fertility and participation.

Allowing for the historical improvements in maternal health but shutting down the decline in the time price of infant formula, the model predicts a rise in both participation at stage 1 and fertility. As shown in the figure, the rise of fertility is smaller, as the peak is 0.4 children lower than in the baseline. The 1960-1930 change in fertility is the model without formula progress is about half of the change in the baseline model (see Table 5). Labor force participation grows less between 1930 and 1950 but attains a higher level in 1960 and after, because of the lower fertility. The 1960-1930 change in participation in the model without progress in infant formula is 10 percentage points at stage 1 and 23 percentage points at stage 2, while it is 6 and 17 percentage points in stage 1 and 2, respectively, in the baseline model.

These results suggest that the improvements in maternal health are necessary to trigger the joint increase in participation and fertility, while the progress in infant feeding plays an important auxiliary role, especially if fertility demand is high.

[36] Participation at stage 2 and human capital investment also do not display any sustained increase.

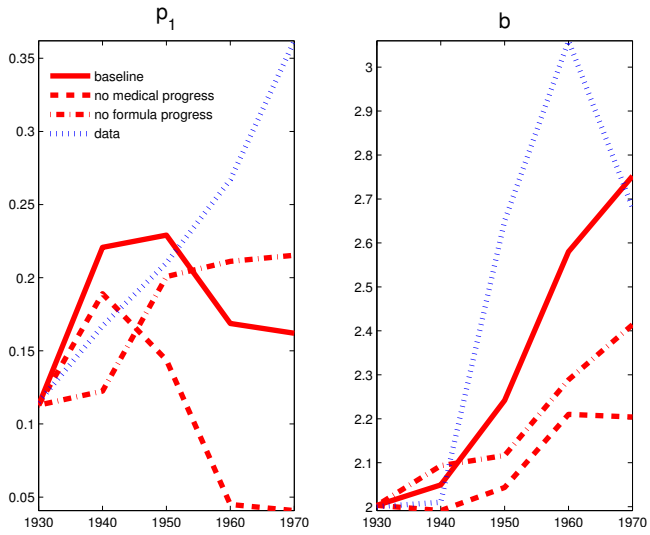


FIGURE 6: No Medical Progress

Notes: p_1 is labor force participation at age 25-34, b is children ever born at age 35-54. The *baseline* version of the simulations allows for time variation in all exogenous variables in the model. The *no medical progress* version sets the time burden of maternal conditions equal to its 1930 value in each year. The *no formula progress* version sets the time price of infant formula equal to its 1930 value in each year. See notes to Figure 5 for data sources.

The continued decline in the infant mortality rate which raises the youth survival probability also has an impact on simulated fertility. Its direct effect on births is negative, as fewer births are required to obtained the desired number of adult children. Though, a higher your survival probability raises the marginal value of an increase in births, which would increase the response of fertility to a decrease in the burden of maternal health. Since the progress in infant mortality is very slow in the simulation years, these effects are small quantitatively, and we do not report them here.

3.4 The role of income effects

Non-labor income plays an important role for women's participation in the model. As shown in figure 4, non-labor income more than doubles over the period of interest. To assess the magnitude of its impact, we simulate a version of the model in which non-labor income is maintained constant at 1930 values. The results are displayed in figure 7 and Table 5.

Absent growth in non-labor income, the growth in participation between 1930 and 1960 is 7 percentage points larger than in the baseline simulation at stage 1, and 5 percentage points larger at stage 2 (see Table 5). Participation at stage 1 continues to grow after 1960 with constant non-labor income, albeit at a lower rate, reaching 0.26 in 1970, whereas it only reaches 0.16 in the baseline simulation. The more pronounced growth in participation leads to a weaker growth in fertility in the simulation with constant non-labor income, relative to baseline. The growth in the number of births between 1930 and 1960 is approximately half than in the baseline, and fertility peaks at a value which is 0.4 children lower. Even if in the model fertility is positively related

to non-labor income, the stronger growth in participation with constant non-labor income offsets this channel in the fertility response.

The strong negative income effect on wife's participation in the model is consistent with historical evidence from labor supply elasticities (Goldin, 1990) and from recent behavior of married women's participation by income and education of the husband.[37] In our model, the size of the income effect is not driven by a large sensitivity of participation to non-labor income, as the calibrated value of the intertemporal elasticity of substitution is very conservative. Instead, it results from the large growth in labor income over the simulation period.

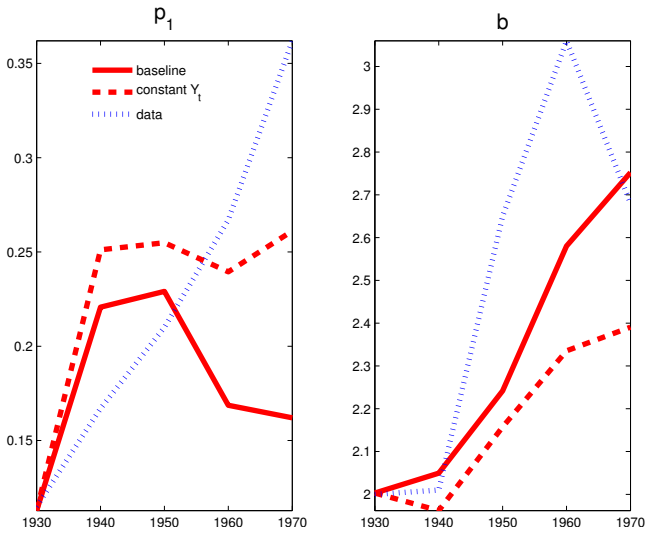


FIGURE 7: Constant Non-Labor Income

Notes: p_1 is labor force participation at age 25-34, b is children ever born at age 35-54. The *baseline* version of the simulations allows for time variation in all exogenous variables in the model. The *constant* Y_t version sets non-labor income equal to its 1930 value in each year. See notes to Figure 5 for data sources.

We run similar experiments with baseline wages and returns to human capital, simulating the model while keeping them constant at 1930 values. We find that the model outcomes are not much affected. This finding is not surprising. While wages at age 25-34 exhibit a modest secular growth, wages at age 35-54 actually decline over time, as shown in figure 4. These two compensatory movements imply that removing wage dynamics does not substantially impact participation or fertility. Similarly, given that we adopt a selection adjustment, and our definition of skill, consistent with our historical perspective, is high school completed, the estimated returns to skill used in our simulation do not exhibit a substantial time variation. Consequently, keeping them constant does not affect model outcomes.

[37] Albanesi and Prados (2014) show that the flattening out of married women's participation since the mid 1990s is due to a decline in participation of women married to high earning husbands, driven by a rise in the skill premium for men.

TABLE 5: Simulation and Counterfactuals: Summary

Difference: 1960 − 1930	p_1	p_2	b	e
Data	15	28	1.1	32
Baseline	6	17	0.6	33
No medical progress	-7	-9	0.2	24
No formula progress	10	23	0.3	24
Constant non-labor income	13	22	0.3	36

Notes: p_1 is labor force participation at age 25-34, p_2 is participation at age 35-54, b is children ever born at age 35-54, e is human capital investment, corresponding to the high school graduation rate. Entries report the 1960-1930 difference for different version of the simulation and in the data. Units are percentage points for p_1, p_2, e, and number of children for b. The *no medical progress* version sets the time burden of maternal conditions equal to its 1930 value in each year. The *no formula progress* version sets the time price of infant formula equal to its 1930 value in each year. The *constant non-labor income* version sets non-labor income equal to its 1930 value in each year. See notes to Figure 5 for data sources.

3.5 Other Forces

Our analysis has shown that progress in maternal health can explain the joint rise in participation and fertility between 1930 and 1960. However, the model is not able to predict the baby bust and also does not generate any further growth in participation after 1960. This is not surprising, given that the forces of progress in our model are virtually exhausted by then, and the burden of maternal conditions drops permanently. Moreover, wages and the returns to human capital grow only modestly, and the growth in non-labor income exerts downward pressure on participation and upward pressure on fertility. The model also over predicts the response of participation and under predicts the rate of growth in fertility in 1940 and 1950.

We show that the model can more closely replicate the behavior of fertility if participation is forced to match its value in the data. To illustrate this point, we run a counterfactual, in which, year by year, we set female unskilled wages to exactly match the value of participation at age 25-34 in the data, maintaining the historical path of all other exogenous variables as in the baseline simulation. This entails reducing wages relative to the baseline simulation in 1940 and 1950, and increasing them post-1960. This counterfactual simulation is intended to capture additional forces influencing the joint behavior of participation and fertility omitted by the model.

The results from this exercise are presented in Figure 8. The left panel plots participation at age 25-34 in the baseline simulation (solid line), in the data (dotted line), and in the counterfactual simulation (dashed line) in each year, and the right panel plots births, in the baseline simulation, in the data and in the counterfactual simulation. The counterfactual simulation by construction matches participation. The lower value of participation for 1940 and 1950 in the counterfactual simulation leads to a higher value of fertility, so that fertility grows strongly in 1940 and 1950, and peaks in 1960 as in the data. In the baseline simulation, fertility grows more slowly in those years, relative to the data, and peaks in 1970. Post-1960, as participation continues to rise in the counterfactual simulation, fertility drops from its peak in 1960, consistent with its empirical

behavior. The peak in fertility in the counterfactual simulation is approximately 0.7 births lower than in the data, while in the baseline simulation, it is only about 0.25 births lower, though it occurs in 1970 rather than in 1960.

We interpret this exercise as capturing other forces that affected participation in recent years but are omitted from our model. These results suggest that these forces are able to reconcile the simulated path of participation to the data, but also much improve the simulated path of fertility in our model.

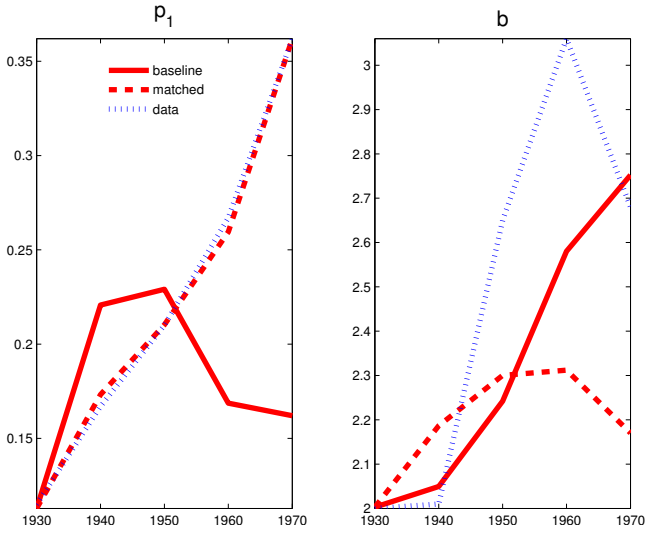


FIGURE 8: Experiment to gauge other forces

Notes: See notes to Figure 5 for data sources. p_1 is labor force participation at age 25-34, b is children ever born at age 35-54. The *baseline* version of the simulations allows for time variation in all exogenous variables in the model. The *matched* version sets unskilled wages in stage 1 to match participation in stage 1 in the model simulation to its empirical value in each year.

The literature points to several forces that could have affected married women's participation, and are omitted by our model. For the years between 1930 and 1960, two important factors that may have contributed to reduce married women's incentive or ability to participate are the presence of marriage bars and cultural aversion to married women in the workforce. Marriage bars consisted in the practice of not hiring married women or dismissing female employees when they married. They were in place until World War II[38] and prevailed in teaching and clerical work, which accounted for approximately 50% of single women's employment between 1920 and 1950 (Goldin, 1991). Cultural aversion to women in the workforce may also have played an important role in slowing down the increase in women's labor force participation.[39]

For the period after 1960, other factors, also omitted in the model, contributed to increase married women's participation, potentially reducing fertility. Perhaps the most notable is the diffusion of oral contraception. The pill became available to married women during the 1960s and

[38] Although they were removed in the public sector in 1941 after a judicial decision.

[39] See Fernández, Fogli and Olivetti (2004), Fernández and Fogli (2009), Fogli and Veldkamp (2011) and Fernández (2013).

to most non-married women in the early 1970s. This development has been linked to the rise in women's education, labor force participation and wages. Goldin and Katz (2002) show that the availability of oral contraceptives contributed to the increase in the number of college graduated women into professional programs starting in the late 1960s, and to the rise in the age at first marriage. Gender biased technological change, as argued by Galor and Weil (1996), also contributed to boost participation of married women while reducing fertility. This process accelerated in the 1980s, resulting in rising returns to experience (Olivetti, 2006) and other labor market shifts (Blau and Kahn, 1999), that further facilitated the rise in participation. The expansion of the service sector, which increased the demand for female labor (Goldin, 1990, Rendall, 2014, and Ngai and Petrongolo, 2014), also played an important role.

Finally, another possible factor is wage discrimination. Even in recent years approximately 10% of the gender differences in earnings cannot be accounted for by observable differences in characteristics that are related to productivity. Albanesi and Olivetti (2009) argue that this unexplained gender earnings differential could be due to statistical discrimination, especially in professional occupations. By depressing female wages, discrimination may have hindered women's incentives to participate in the workforce in the early years. On the other hand, a decline in discrimination may have provided an additional incentive to participate in later years.

4 Conclusion

Our results suggest that improvements in maternal health were critical to the joint evolution of married women's participation and fertility in the United States during the twentieth century. These developments hold an important lesson for emerging economies, where maternal mortality and morbidity are still quite high, and women's education and participation in market work often still very low. Indeed, reducing maternal mortality in developing countries is one of the United Nations' Millennium Development Goals. Our analysis suggests that, in addition to being important from a human rights and welfare perspective for women, maternal mortality reduction could potentially accrue large economic gains for developing economies as a whole.

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A Data Appendix

This section lists all the data sources and describes in detail the variables discussed in the empirical analysis and used in the calibration.

A.1 Demographics

Total Fertility rate and Cohort Total Fertility Rate: U.S. Cohort and Period Fertility Tables 1917-1980, National Institute of Child Health and Development, National Institutes of Health, compiled by Robert L. Heuser. Available at http://opr.princeton.edu/archive/cpft/. Key reference is Hauser, Robert. *Fertility Tables for Birth Cohorts by Color: United States 1901-1973.* (Rockville, MD: National Center for Health Statistics, 1976). 1980-2000: National Center for Health Statistics, "Births: Final Data for 1998," by S.J. Ventura et al., National Vital Statistics Reports 48, no. 3 (2000); National Center for Health Statistics, "Births: Final Data for 1999," by S.J. Ventura et al., National Vital Statistics Reports 49, no. 1 (2001). National Center for Health Statistics, "Births: Final Data for 2000," by J.A. Martin et al., National Vital Statistics Reports 50, no. 5 (2002).

Median age at first marriage: Series A 158-159 in Historical Statistics of the United States (1975). Median age at first birth: Data on first birth by age of mother from the National Center of Health Statistics (http://www.cdc.gov/nchs/data/statab/t991x02.pdf). We use information on number of women in each age group (Series A 119-134, Historical Statistics of the United States, 1975) to compute median age at first birth in 1920. Median age at last birth: Glick (1977, Table 1.)

A.2 Earnings

We estimate earnings and returns to human capital based on 1940 to 2000 data from the Integrated Public Use Micro Sample (IPUMS) of the decennial Census of the United States (Ruggles et al. 2010). For all decades we use the 1% samples (for 1970, we use the 1% State sample). Our sample includes white married women (and men) aged 25 to 54. We exclude individuals living in farms, as well as those living in group quarters (e.g. prisons, and other group living arrangements such as rooming houses and military barracks).[40]

We use total wage and salary income (incwage) and weekly earnings, obtained dividing incwage by weeks worked in the previous year. Earnings are adjusted for inflation using the Consumers Price Index provided by the Census (see "inctot" variable). Top coded annual earnings are replaced by 1.5 times the top coded values for the years 1940 to 1980. For 1990 and 2000, amounts exceeding top coded values are expressed as the state medians of values above top codes, hence no adjustments are made. The weeks worked variable is available only in intervals for 1960 and 1970, thus for these years weeks worked represent the midpoint of the intervals.

All our estimates and statistics are obtained using person weights (perwt) for all years except 1950, for which we use sample line weights (slwt). This is because income and work variable are

[40] That is, we select observations with group quarters status equal to 1, "Households under 1970 definition."

only available for sample line individuals in 1950.

In all calculations the sample is further restricted to individuals with nonzero, non missing wages who worked at least 48 weeks last year. For women, we obtain selection adjusted estimates of weekly earnings for the unskilled (by age) and returns to skill by running a standard Heckman two step procedure where the dependent variable is the logarithm of weekly earnings and we include a dummy for higher education defined as having at least 12 years of schooling.[41] In the selection equation the censored observations are those who worked fewer than 48 weeks last year. The exclusion restrictions are husband's real weekly earnings, number of children less than 5 years old (nchlt5) and number of children between 5 and 12 years old (obtained as the difference between census variables nchild and nchlt5.

A.3 Female Labor Force Participation

Labor force participation (LFP) of white married women: Goldin (1990, Table 2.2) which present comparable 1890 to 1980 data disaggregated into five age groups: 15-24, 25-34, 35-44, 45-54, 55-64. We use Census IPUMS data (sample inclusion rules same as in section A.2) to update the series to 2000. Since data are not available for 1910 LFP by age for this decade is obtained by linear interpolation of the appropriate statistics between 1890 and 1920. The LFP statistics by cohort are computed as follows. The 1920 calibration target for LFP of "young" (age 25 to 34) married women corresponds to the LFP of women born in 1886-1895 (that is, married women age 25-34 in 1920). The 1920 target for LFP of "old" (age 35 to 54) married women is obtained by averaging LFP statistics for the 35-54 age group across two cohorts: 1866-1875 and 1876-1885. Similarly, for all the other decades, LFP of old married women is obtained by averaging (with the appropriate population weight obtained from Haines and Sutch (2006)) LFP of white married women aged 35-44 and 45-54.

A.4 Home Hours

We use evidence on time use of mothers by children's age to estimate the time spent in child care activities in each stage of life. Our main reference is Zick and Bryant (1996) who reports statistics on primary and secondary time spent in childcare by two-parents, two-child households based on the 1977-78 Eleven State Time Use Survey (ESTUS) which allowed for a detailed study of the different components of family care. Entries in Table A0 report average (weekly) primary and secondary care time spent by mothers, by age of the younger child, based on the statistics in Table 1 in Zick and Bryant (1996).

Table A0. Average primary and secondary care by mothers

Age of child	Mean weekly hours per child
<1	37.9
1	33.3
2-5	23.5
6-11	9.8
12-17	8.5

[41] For comparability across all years in all our calculations we use the census variable (educ) which indicates respondents' educational attainment, as measured by the highest year of school or degree completed.

In our calculation of the child care time requirement during stage 1, we assume that a child is born during the first year of this stage and is present in every subsequent year. Using the numbers in Table A0 we then compute total average weekly hours spent in general childcare during stage 1 as $((37.9-15)*1+33.3*1+23.5*3+9.8*5)/10 = 17.57$. Note that for the first year of stage 1 we subtract the infant feeding time of 15 weekly hours from Brossard (1926). Assuming that the total weekly time endowment is 16 hours of (non-sleep) time per day for 7 days a week and 52 weeks per year, we obtain our estimate of the parameter ψ_1 as follows: $\psi_1 = 17.57*52/(16*7*52) = 0.157$.

For the second stage of life, we assume that children age 6-11 are present for 5 years, and children 12-17 are present for 10 years. We compute the average weekly hours per child based on this assumed age distribution, as follows: $(9.8*5+8.5*10)/20 = 6.71$. Given the time endowment, we obtain $\psi_2 = 6.71*52/(16*7*52) = 0.060$.

A.5 Mortality Data

Maternal Mortality:1900-1920: Loudon (1992,) Appendix Table 5. 1921-1998: Series Ab924, Haines (2006a). Maternal mortality by causes of death: 1920-1940: Vital Statistics Rates in the United States 1900-1940, Table 12. 1941-1949: yearly editions of Vital Statistics of the United States (VSUS), Part I, Natality and Mortality Data. 1950-1959: yearly editions of VSUS, Volume II, Mortality Data. 1960-1978: yearly editions of VSUS, Volume II, Mortality, Part A. 1979-1998: "1979-1998 Archive" accessible on-line at http://wonder.cdc.gov/cmf-icd9-archive1998.html. **Fetal deaths:** The 1918 data point is from Table A and B from the 1931 VSUS volume on "Births, Stillbirth and Infant Mortality Statistics." Rates refer to fetal deaths at any gestational age. 1920-1992: series Ab912, Haines (2006a). Starting in 1942 the rates only include fetal deaths where the gestational period was 20 weeks or more. 1995-2003: National Vital Statistics Reports, Vol. 55. No. 6, February 21, 2007. Neonatal deaths at less than 7 days: 1915-1960: Vital Statistics Rates in the United States 1940-1960, Table 38. 1961-1970: VSUS 1970, Volume II Mortality, Part A, Table 2-4. 1971-1993: VSUS 1980, 1989-90, 1993, Volume II Mortality, Part A, Table 2-3. 1995-1998: "Linked Birth / Infant Death Records 1995-1998" accessible on-line at http://wonder.cdc.gov/lbd-icd9.html. 1999-2000: "Linked Birth / Infant Death Records 1999-2002" accessible on-line at http://wonder.cdc.gov/lbd-icd10-v2002.html. **Mortality rates by gender and cause of death:**1900-1940: Vital Statistics Rates in the United States 1900-1940, Table 15. 1960: Vital Statistics Rates in the United States 1940-1960, Table 63 and Table 1.M in VSUS 1960, Vol. 2a for puerperal causes.

A.6 YLD Calculations and Data Sources

YLD for a given cause is measured as:

$$YLD = I \times D \times DW,$$

where I is incidence, D represents duration and DW are disability weights estimated by the WHO.

In our calculation we use historical data on duration and incidence of maternal morbidity and WHO disability weights for four maternal conditions: maternal hemorrhage, maternal sepsis, hypertensive disorders of pregnancy and obstructed labour.

Incidence and Duration of Maternal Morbidity

Maternal Hemorrhage: Loudon (1992) reports that 5.7% of all pregnancies would develop some form of illness due to maternal hemorrhage. Using the 1920 stillbirth rate (equal to 3.94%) we obtain an estimate of 5.5% for the incidence of disability due to hemorrhage (as a percentage of live births). According to WHO maternal hemorrhage can have permanent consequences such as severe anaemia. Consequently the duration of the disability due to this condition is set equal to the length of each model period (in months).

Hypertensive disorders: According to historical studies reported in Loudon (1992), toxemia develops in about 10 percent of all pregnancies. Using the 1920 stillbirth rates we obtain an estimate of 9.6% for the incidence of morbidity caused by hypertensive disorders. According to WHO hypertensive disorders of pregnancies can cause neurological sequelae which are permanent. Hence the duration of hypertensive disorder is set equal to the length of each model period (in months).

Obstructed Labor: Table A1 reports the information on the frequency and length of disablements due to obstructed labor used to estimate duration for this condition. The Table reproduces Table XLIII in Kerr (1933).

Table A1: Cases of Obstructed Labor in Dr. Kerr's Ward, 1928-1932

Condition	Frequency	Duration of Disablement (months)
Perineal Laceration		
Complete	0.028	42
Incomplete	0.279	52
Injury urethral sphynter	0.002	84
Cervical Laceration	0.298	48
Prolapse Complete	0.022	156
Prolapse Incomplete	0.074	84
Cystocele	0.088	78
Rectocele	0.027	72
Retro-displacement	0.176	36
Fistula vescico-vaginal	0.003	7
Fistula vescico-rectal	0.001	36
Ruptured Uterus	0.001	7
Total Number of In-Patients	2000	
Total Number of Lesions	1346	

Taking a weighted average of the months of disablement (column 3) with frequency weights (column 2) we obtain the estimate of 55.67 months of disablement for obstructed labor reported in section 2.1.1. The incidence of morbidity due to this condition is given by 0.673. This is the fraction (1346 out of 2000) of in-patients in Dr. Kerr's ward who actually had lesions. Given the 12% overall morbidity rate, we obtain an estimate of 8.1% for the overall incidence of morbidity due to obstructed labor (as a percentage of all births). According to the WHO obstructed labor could also cause stress incontinence - which is a permanent disability. Its duration is set to be equal to the length of each model period (in months).

Disability Weights

Table A2 reproduces relevant information from Annex Table 3 "Age-specific disability weights for untreated and treated forms of sequelae included in the Global Burden of Disease Study,"

available at http://www.who.int/healthinfo/bodgbd2002revised/en/index.html. We report only one set of entries since DW for treated and non-treated form are identical in this case.

Note that, as discussed in section 2.1.1, in our calculation of YLD we do not take into account infertility due to maternal sepsis, since infertility does not directly reduce labor market productivity.

Table A2: Age-specific disability weights, maternal conditions

Sequela	15-44	45-60
Maternal sepsis		
Infertility	0.180	0.000
Maternal hemorrhage		
Sheehan syndrom	0.065	0.065
Severe anemia	0.093	0.090
Hyperthensive disorders of pregnancy		
Neurological sequelae	0.388	0.397
Obstructed Labor		
Stress Incontinence	0.025	0.025
Rectovaginal fistula	0.430	0.000

Computation of YLD The disability weights provided by the WHO are for age 15-44 and 45-60. We adapt them to our model period using the WHO disability weights for age 15-44 for stage 1, which corresponds to age 25-34. For stage 2, which corresponds to age 35-54, we use an average of the WHO weights at age 15-44 and 45-60. We adapt the duration for each condition to our model period. Therefore, using the above data sources and assuming a 10-year childbearing period (120 months) we obtain:

$$
\begin{aligned}
&YLD^{25-34}_{\text{Pregnancy}} = 0.222 * 9 = 1.98 \text{ months};\\
&YLD^{25-34}_{\text{Obstructed Labor}} = 0.081 * (0.43 * 55.67 + 0.025 * 120) = 6.56 \text{ months};\\
&YLD^{25-34}_{\text{Sepsis}} = 0 \text{ months};\\
&YLD^{25-34}_{\text{Hypertensive Disorders}} = 0.388 * 0.096 * 120 = 4.47 \text{ months};\\
&YLD^{25-34}_{\text{Hemorrhage}} = 0.158 * 0.055 * 120 = 1.04 \text{ months}.
\end{aligned}
$$

Consequently $YLD^{25-34} = (1.98 + 6.56 + 0 + 4.47 + 1.04) = 14.05$ months (1.17 years) for each pregnancy.

We also compute the YLD index for post-childbearing years to capture the burden of permanent conditions in our quantitative analysis. Assuming the post-childbearing period to correspond to age 35-54 as in the model, we obtain $Y^{35-54}_{\text{Obstructed Labor}} = 0.55$, $Y^{35-54}_{\text{Hemorrhage}} = 2.29$, $YLD^{35-54}_{\text{Hypertensive Disorders}} = 10.30$ in months, so that $YLD^{35-54} = (2.29 + 0.55 + 10.30) = 13.13$ months (1.09 years).

A.7 Breast Feeding Practices

We rely on several data sources to construct our data series on breastfeeding rates at 6 months.

The data points for 1918 are obtained by averaging data on breastfeeding from a series of studies for different geographical areas conducted by the Children Bureau during the period 1917-1919 (see Apple, 1987, Table 9.1).

Breastfeeding rates for children born between the early 1930s and the early 1970s are from Hirschman and Butler (1981) based on the 1965 National Fertility Study and the 1973 National Survey of Family Growth (NSFG). The rates are extrapolated from Figure 1 in Hirschman and Butler (1981), which reports the proportion of mothers breastfeeding their first child by duration of breastfeeding and by mother's birth cohort (in five-year intervals). We obtain the statistics by child's year of birth using data on mother's age at first birth from Glick (1977, Table 1). The statistics are available for: 1935, 1941, 1947, 1951, 1955, 1959, 1965 and 1969 (corresponding to the middle point of the five-year intervals).

For 1971 to 2001 breast feeding rates are from the appendix table in Ryan, Wenjun and Acosta (2002), based on the Ross Laboratories Mothers Survey (RLMS.) The statistics from RLMS are comparable to those obtained based on NSFG when the two series overlaps (Ryan et al., 1991).

A.8 Monetary Cost of Breast Feeding

Table A3 reports our estimates of the average daily intake of infant formula, by gender, for an infant of median weight. The number of daily formula feedings varies by infant's age. As solid food is introduced, the number of daily feedings decreases (Source: Pediatric Advisor, University of Michigan Health System, http://www.med.umich.edu/1libr/pa/pa_formula_hhg.htm). The same data source also reports information on the quantity of formula by feeding. This varies by infant's age and weight. Newborns: 1 ounce per feeding initially, up to 3 ounces per feeding by day 7. After day 7: Amount per feeding (in liquid ounces) should be equal to a half of the baby's weight (in pounds). We use this information as well as the 2000 Infant Growth Charts from the Center for Disease Control of the National Center of Health Statistics (http://www.cdc.gov/growthcharts/) to estimate the per feeding and total daily intake of formula in Table A3.

Table A3. Average daily intake of baby formula by gender (liquid ounces)

	No. feedings (per day)		Liquid ounces (per feed)		Daily Intake Boy		Daily Intake Girl	
	min	max	Boy	Girl	min	max	min	max
$<$ 1 month	6	8	8	7.5	24	32	22.5	30
1-3 months	5	6	12	12	30	36	30	36
3-7 months	4	5	18	17	36	45	34	42.5
7-12 months	3	4	22	21	33	44	31.5	42

The average daily cost of exclusively breast feeding an infant is then obtained by multiplying the resulting quantity by the price of a ready-to-feed liquid ounce of Similac. Table A4 summarizes the resulting estimates of the monthly and annual cost of bottle feeding in 1936 (expressed in 2000 USD). Note that because of data availability, the 1936 share is computed using 1939 labor income.

Table A4. Cost of bottle feeding (2000 USD)

	Boys		Girls	
	min	max	min	max
Monthly cost				
$<$ 1 month	21.7	28.9	20.3	27.1
1-3 months	27.1	32.5	27.1	32.5
3-7 months	32.5	40.6	30.7	38.4
7-12 months	29.8	39.7	28.4	37.9
Annual Cost				
	354.8	455.0	339.5	435.2

A.8.1 Price of Similac

The time series for the price of Similac is constructed from historical advertisements from the Chicago Tribune, the Los Angeles Times and the Washington Post for products on sale in drugstore chains in these three cities. We have monthly information on price, quantity and type (powder, concentrated liquid, ready-to-feed) of formula for the period 1935-1986.

We only use powder and concentrated liquid Similac in the construction of our price index. These two products can be considered as quality-equivalents since the only differences between the two are related to the proportion of water and the differential amount of time required to effectively mix powder or concentrated liquid with water. The price per ready-to-feed liquid ounce of formula is obtained using the following conversion rules. Based on the instructions on current Similac labels: 25.6 ounces of powder can make approximately 196 fluid ounces of formula; 13 ounces of concentrated liquid can make 26 fluid ounces of formula. The price of one liquid ounce of formula is obtained by dividing the (real) price of the product by the quantity of formula (in liquid ounces) that can be obtained with its content.

There is no record on the price of Similac in the Los Angeles Times from July 1936 to March 1948 and in the Washington Post from October 1942 to May 1948. For these years the series is based on the price of Similac for the Chicago area alone. If the information for one year is missing we interpolate prices across the two adjacent years. For some years we also have information on the regular (non sale) price of the product. However, this information is very limited and cannot be used to obtain a consistent price series. Nonetheless, it is interesting to note that a 16 ounces can was often referred to as the '$1.25 Similac' and not by its weight. This seems to suggest that the non-sale price of the product was $1.25 for a long time (from 1935 to the late 1940s/early 1950s). Over time we find more and more ads for the '$1.25 Similac' at discount prices, suggesting that the price of the formula was closer to its sale price in the early 1950s than it was in the mid 1930s. It follows that we are probably underestimating the decline in the price of Similac over this period.

The data series is updated to 2000 by using data on the average U.S. price of infant formula (powder and liquid concentrate) from Oliveira and Davis (2006).

A detailed discussion of issues related to the construction of the Similac price series as well as additional data on 19th century first-generation milk-based formulas is provided in an online appendix available at http://people.bu.edu/olivetti/papers/online_appendix_babyformula.pdf.