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GENDER ROLES AND MEDICAL PROGRESS

Stefania Albanesi
Claudia Olivetti

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Cambridge, MA 02138
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ABSTRACT

The entry of married women into the labor force is one of the most notable economic phenomena of the twentieth century. We argue that medical progress played a critical role in this process. Improved maternal health alleviated the adverse effects of pregnancy and childbirth on women's ability to work, while the introduction of infant formula reduced mothers' comparative advantage in infant feeding. We construct economic measures of these two dimensions of medical progress and develop a quantitative model that aims to capture their impact. Our results suggests that these advances, by enabling women to reconcile work and motherhood, were essential for the rise in married women's participation and the evolution of their economic role.

Stefania Albanesi
Columbia University
1022 International Affairs Building
420 West 118th Street
New York, NY 10027
and NBER
sa2310@columbia.edu

Claudia Olivetti
National Bureau of Economic Research
1050 Massachusetts Avenue
Cambridge, MA 02138
olivetti@bu.edu

1 Introduction

The entry of married women into the labor force is one of the most notable economic phenomena of the twentieth century and has led to a revolutionary change in women's economic role. We examine the contribution of advances in reproductive medicine and infant feeding to this process and find that they played a critical role.

Our point of departure is that, up until the early decades of the twentieth century, poor maternal health and lack of reliable alternatives to breast feeding made it particularly hard to reconcile motherhood and work outside the home. Consider a typical woman born around 1900[1]. She married at 21 and gave birth to more than three live children between age 23 and 33. The high fetal mortality rate implied an even greater number of pregnancies, so that she would be pregnant for 36% of this time. Health risks in connection to pregnancy and childbirth were severe. Septicemia, toxaemia, hemorrhages and obstructed labor could lead to prolonged physical disability and, in the extreme, death. In 1920 one mother died for each 125 living births. At a rate of 3.6 pregnancies per woman, the compounded risk of death from maternal causes was 2.9%[2]. 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 beyond their childbearing years. In addition, due to the lack of reliable alternatives, most infants were exclusively breast fed. Women would then be nursing for approximately a third of the time between age 23 and 33. Since the average time required to feed one child ranges between 14 and 17 hours per week, with a 40 hour workweek, mothers would be nursing for 35%-43% of their potential working time in childbearing years.

Not surprisingly given this burden, few married women worked. Only 5.4% of married women aged 25 to 34 were in the labor force in 1900. Starting with this cohort, married women experienced a significant rise in labor force participation, as shown in Figure 1. Married women's participation rose from 2.8% in 1890 to 70% in 1990 during childbearing years and beyond, leading to a sizeable increase in lifetime participation. By contrast, participation for never married women was a relatively high 59% in 1900 and rose at a much slower pace, reaching 85% in 1990. We argue that the improvement in maternal health and the diffusion of infant formula were critical to this process. Both these dimensions of medical progress begin to exert their impact in the 1930s and are mostly exhausted by 1960.

The improvement in maternal health was mostly the result of *general* scientific and medical advances in the early 1900s. The development of bacteriology, the introduction of sulfominydes and antibiotics, and the diffusion of blood banks dramatically decreased the death rate from sepsis and hemorrhage. More specific interventions, such as the standardization of obstetric practices and the increased availability of pre-natal care, reduced the incidence of hypertensive disorders of pregnancy and obstructed labor, a causal factor for many forms of post-partum disability. These developments lead to a stark decline in maternal mortality and a rise in the female-male differential in life expectancy at age 20 from 1.5 years in 1920 to 6 years in 1960. The improvement in maternal health also led to a decline in stillbirths, which in turn reduced the number of pregnancies required to achieve the desired fertility. To quantify the effect of improved maternal health, we estimate the burden of maternal conditions based on historical data on the incidence and duration of the

[1] Data from Historical Statistics of the United States, Hauser (1976) and Glick(1977). See the Data Appendix for detailed information and sources for all data used in the Introduction.

[2] 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.

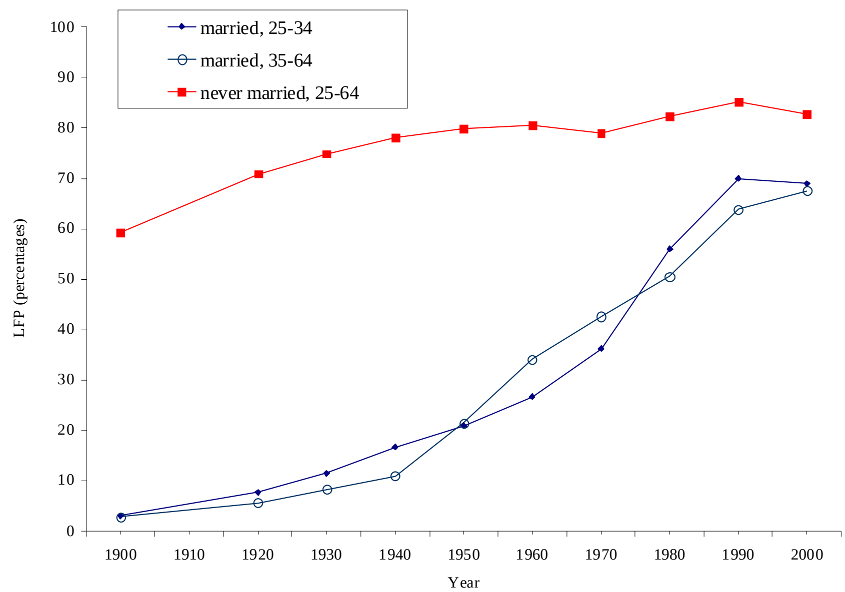

Figure 1: Female Labor Force Participation by Age and Marital Status

corresponding symptoms, combined with the World Health Organization measure of the intensity of the corresponding disablement. We construct an index of the decline over time in this burden based on the evolution of maternal and fetal mortality. According to our estimates, the years lost to disabilities associated with maternal conditions declined from 2.31 per pregnancy in 1920 to just 0.17 in 1960.

The development and commercialization of infant formula were the result of progress in nutrition and pediatrics, specialties that developed at the turn of the twentieth century to reduce infant mortality. The first type of "humanized" formula, so called because it replicated the nutritional content of human milk, was first commercialized in the late 1920s. We construct a measure of the time price for infant formula using newly collected data from historical newspapers. The time price declines by 82% between 1935 and 1960, and remains approximately constant thereafter. This decline can be interpreted as a measure of the progress in infant feeding over this time period. Infant formula reduces mothers' comparative advantage in infant care.

We incorporate these measures of medical progress in a quantitative model to assess their role in accounting for the rise in labor force participation of married women. The model hinges on two critical components. First, agents can make a pre-marital investment in market skills, which increases their future productivity. Prior to this investment, men and women are equally productive in market work. Additionally, married households engage in the production of *infant goods*, that is activities strictly connected to the presence of infants in the household, including pregnancy, childbirth and infant feeding. *Only* wives can contribute to the production of infant goods during child bearing years. The time required for infant good production is given by the time associated with pregnancy, childbirth and post-partum conditions, plus the time for infant feeding. While the first component is taken as given, households *choose* whether to breast or bottle feed. Bottle feeding requires infant formula, instead breast feeding does not generate any pecuniary costs. The time and expenditure required for infant good production are scaled by the number of children, which is exogenous in the model. Households also produce general home goods, that is activities such as meal preparation, cleaning, and other chores. Wives and husbands have equal ability in general home good production and their individual contribution is determined efficiently, based on their relative opportunity cost in terms of foregone labor earnings.

Medical progress affects women's participation in the model in two ways. The corresponding reduction in the burden of maternal conditions and, via the decline in the time price of infant formula, the adoption of bottle feeding have a direct positive effect on married women's participation during childbearing years. This is turn increases women's incentives to invest in market skills before marriage, raising their potential wage relative to their husbands. As a consequence, married women's participation rises in *all* stages of the lifecycle, their earnings relative to men rise, and their contribution to general home production also declines.

To assess the quantitative relevance of this mechanism, we simulate the model, confronting overlapping generations of agents with the estimated historical series for the burden of maternal conditions and the time price of infant formula. The initial point is calibrated to match US data on participation, home hours and earnings by gender, as well as breast feeding rates and adoption of home appliances in 1920. We run several experiments to evaluate the impact of each dimension of medical progress in isolation. Following Greenwood, Seshadri and Yorugoklu (2005), we also allow for advances in general home production, as proxied by the decline in the time price of appliances.

We find that medical progress is indeed a powerful force. The decline in the burden of maternal conditions alone can generate the fourfold increase in the labor force participation of married women in childbearing years between 1920 and 1965. This result hinges on the critical role of medical progress in enabling married women's participation to rise contemporaneously with fertility during the Baby Boom, between 1940 and 1960. The effect of infant formula on female participation is positively related to the fertility and the burden of maternal conditions. If fertility is high and maternal mortality is low, women have an incentive to participate and this is when infant formula appears to be most valuable. The decline in the time price of infant formula adds up to 10% to participation in child bearing years in 1960 at the peak of the Baby Boom. Despite the more than ten-fold decline in the time price of home appliances in the course of the twentieth century, their diffusion cannot account for the contemporaneous rise in fertility and participation of married women between 1940 and 1960, though it plays a more significant role between 1960 and 1975.

Our simulations imply that progress in reproductive medicine and infant feeding alone could drive married women's participation close to 50% as early as 1965. In the data, this threshold is attained after 1970. It is not surprising that the model overpredicts married women's labor force participation between 1935 and 1965, since we abstract from a number of factors that had an adverse effect on participation in those years. These include "marriage bars," which were in place for female employees until World War II (Goldin, 1990), wage discrimination (Goldin, 2002), as well as cultural forces, such as aversion of women in the workforce (Fogli and Fernández, 2009) and a bias against working women in the marriage market (Fernández, Fogli and Olivetti, 2004). Similarly, the model under-predicts participation relative to the data after 1980. Again, this is not surprising since the dimensions of medical progress we consider are mostly exhausted by 1960, while starting in the late sixties several additional factors emerged. These include the diffusion of oral contraception (Goldin and Katz, 2002), shifts in the labor market that favored women (Blau and Kahn, 1999), and an attenuation of the cultural biases against working women. We quantify these forces by computing their impact on the return to pre-marital investment in market skills in the model. We find that marriage bars and negative cultural forces active between 1935 and 1960 are equivalent to a 50% reduction in the returns to pre-marital labor market investments relative to the calibrated value. On the other hand, the favorable shifts in the labor and marriage market, and the other positive forces operating starting in the 1970s, are equivalent to a 46% increase in the returns to pre-marital investment in market skills in the model.

Our analysis makes several contributions. It is the first to consider the impact of improved maternal health and infant feeding on the evolution of married women's labor force participation. While these forces began to exert a tangible effect on women's lives in the early 1930s, when married women's participation also started to rise systematically, the public health initiatives and the scientific discoveries that led to these advances date as far back as the mid 19th century and largely preceded the rise in married women's participation. By contrast, the diffusion of home appliances largely occurred after World War II and may well have been driven by rising demand from working women.[3]

From a theoretical standpoint, we isolate dimensions of medical progress that disproportionately affect women's health and incorporate them into a macroeconomic model of household behavior to quantify their impact. In our model, *both* the division of labor within the household and gender differences in wages are endogenous. Thus, we are able to generate predictions for the *joint* evolution of women's home hours, labor force participation and earnings relative to men. This constitutes a step forward relative to the existing literature. Jones, Manuelli and McGrattan (2003) examine the effect of a declining gender wage gap on married women's participation in the post-war period, but they treat this gap as exogenous. Greenwood, Seshadri and Yorugoklu (2005) examine the impact of advances in home appliances on female participation and treat both the household division of labor and gender wage differentials as given. By contrast, biological factors are the only source of gender differences in our model. 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 biological comparative advantage.

Finally, we also make an empirical contribution by constructing an economic measure of the burden of maternal conditions and its evolution over time based on historical data on maternal morbidity that had not been previously used in economics. Our methodology is related to the literature on the effects of health on growth (Weil, 2007, and Ashraf, Lester, Weil, 2008). In addition, we collect new historical data on the price of infant formula to measure progress in infant feeding.

While we treat fertility as exogenous, it is reasonable to presume that the demand for children was affected by such a dramatic decline in their cost. The fact that the sharp reduction in maternal mortality between 1935 and 1955 precedes the mid twentieth century Baby Boom by a handful of years is likely not coincidental. Indeed, Albanesi and Olivetti (2009) find that the rise in fertility during the years between the late 1930s and the early 1960s was highest for US states and cohorts of women that experienced the greatest improvements in maternal health. In this paper, we concentrate on the role of improvements in maternal health and infant feeding in enabling married women to participate in the labor force *despite* their high fertility. Albanesi and Olivetti (2009) analyze instead the impact of medical progress, in the form of reduced maternal, infant and child mortality, on fertility decisions.

The paper is organized as follows. Section 2 briefly describes the medical advances responsible for the improvement in maternal health and documents the diffusion of infant formula. This

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

section also derives our measure of maternal health and explains the construction of the time price of infant formula. Section 3 presents our analytical framework. Section 4 discusses our calibration strategy and presents the results of our quantitative analysis. Section 5 concludes.

2 Evidence on Medical Progress

We now document the two components of medical progress that contributed to alleviate the time commitment associated with women's maternal role: the advances in reproductive medicine that reduced the burden of maternal conditions and the introduction and diffusion of infant formula. The detailed list of sources and references for this section can be found in the Data Appendix.

2.1 Advances in Maternal Health

The risk of temporary or permanent disability, and potentially death, associated with childbirth implied that mothers were subjected to a very significant health toll (Loudon, 1992, and Leavitt, 1986) until the early decades of the 20th century. In 1921, septicemia (40%), toxemia (27%), obstructed labor (10%) and hemorrhages (10%) were the main causes of maternal death. Sepsis, toxaemia and obstructed labor were also the leading causes of maternal morbidity and gave rise to the most debilitating conditions associated with the child bearing process, such as puerperal fever, neurological disorders, rectovaginal fistula and other severe forms of perineal lacerations.[4] Obstructed labor was very common, due to pelvic deformation from poor nutrition, and contributed to imperil the health of the child, as well as that of the mother.

We now examine the impact of medical progress on maternal mortality and female life expectancy and then construct a measure of the burden of maternal conditions and describe its evolution over time.

2.1.1 Maternal Mortality and Female Life Expectancy

The number of maternal deaths dropped from 690 to 7.1 per 100,000 live births between 1915 and 1995. The decline in maternal mortality started in 1933 and continued precipitously in the ensuing decades. In 1940, maternal mortality had declined by 39% relative to 1933, and by 90% in 1953. Figure 2 shows the evolution of maternal mortality by cause. The most striking decline occurs for deaths due to sepsis, which drop from 275 in 1923 to 5.5 per 100,000 live births in 1955. All other factors of mortality also drop in this period.

Several factors contributed to the decline in maternal mortality[5]. The first is medicalization and hospitalization of childbirth. Physicians gradually entered the birth room starting in 1850, and after 1935 births increasingly took place in hospitals. The intervention of physicians did not initially contribute to a reduction in maternal mortality.[6] Excessive operative interventions and their exposure to other patients with communicable diseases actually increased the risk of infection before germ theory was widely accepted and antibiotics were available. However, the involvement of physicians eventually led to the development of standardized obstetric practices that reduced

[4] Mothers rarely survived hemorrhages before blood banking was introduced.

[5] See Loudon (1992) for more detail.

[6] See Thomasson and Treber (2004) for an empirical analysis of the consequences of the hospitalization of childbirth on maternal mortality.

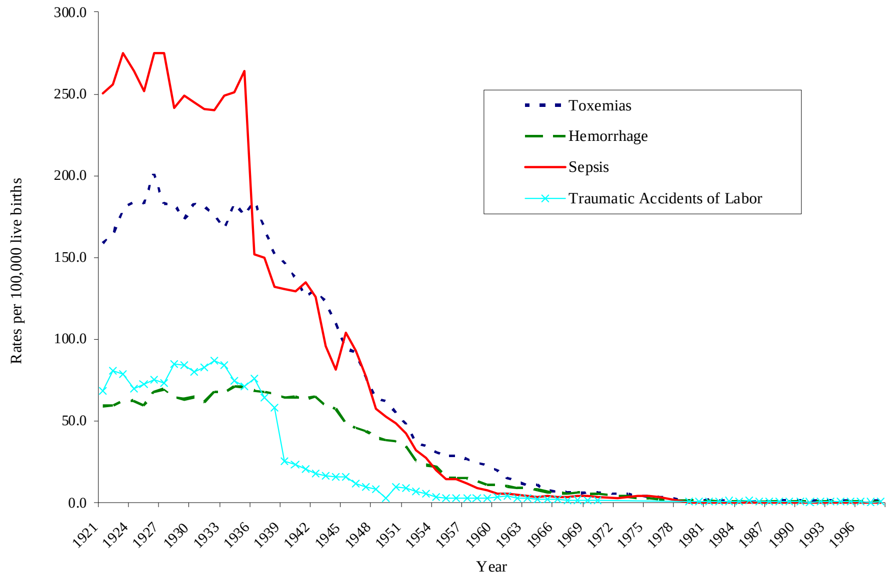

Figure 2: Trends in causes of maternal deaths

the incidence of trauma during labor[7]. Scientific discoveries and advances in general medicine starting in the 1930s had a particularly positive effect on maternal health. The introduction of sulfonamide drugs (1935), blood banking (1936) and the discovery of the antibiotic effects of penicillin (1939-1942) were critical for the remarkable decline in maternal mortality. Infection could now be easily treated and transfusions could replace blood lost in hemorrhages. Improved pre-natal care determined a decline in the incidence of death by toxaemia. The generalized shift from home to hospital of childbirth also occurred in the mid-1930s, with the advent of electronic imaging and advanced neonatal therapies that could only be administered in a hospital setting. The percentage of births that took place in hospitals rose from 36.9% in 1935 to 82% in 1946 and to 94.4% by 1955 (see Table 1 in Taffel, 1984.)

The decline in maternal mortality was associated with a sizeable rise in the female-male differential in adult life expectancy at age 20 starting in 1930, as shown in Figure 3. Between 1900 and 1930, the female-male differential in life expectancy at age 20 is approximately constant, despite the substantial decline in the overall mortality rate, which dropped by 42% for men and by 36% women.[8] Maternal mortality declined by 5% between 1900 and 1930, while it declined by 84% between 1930 and 1960, when the decline in overall mortality was twice as large for women

[7] The New York Academy of Medicine published in 1933 a shocking study of 2,041 maternal deaths in childbirth. At least two-thirds, were found to be preventable. There had been no improvement in death rates for mothers in the preceding two decades and newborn deaths from birth injuries had actually increased. The investigators found that many physicians simply didn't know what they were doing. The White House followed with a similar national report and this precicipated the efforts to standardize obstetric practices and train physicians.

[8] Noymer and Garenne (2000) show that the *drop* in the female-male differential in life expectancy between 1915 and 1920 is a consequence of the influenza epidemic of 1918 on female-male mortality differentials for tuberculosis. Influenza increased mortality associated with tuberculosis. Though in general tuberculosis mortality rates were higher for men, they increased for women during the influenza outbreak of 1918, temporarily closing the gender gap.

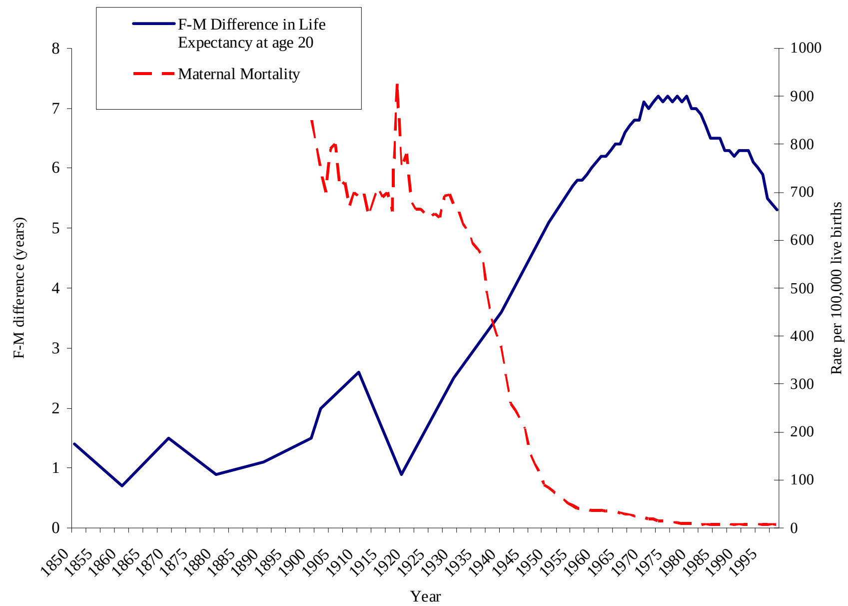

Figure 3: Trends in Maternal Mortality and the Gender Differential in Life Expectancy at age 20

than for men. Consequently, the female-male differential in life expectancy at age 20 more than doubled over this period. The decline in maternal mortality can explain two-thirds of the rise in the female-male differential in life expectancy, and the correlation coefficient between the two series is -0.94, significant at the 1 percent level.

Life expectancy and adult survival rates are a widely used index of health and linked to labor productivity. Based on this evidence, improvements in health resulting in increased life expectancy are also associated with a decline in the burden of disease while alive.[9] On this basis, we construct an index of the burden of maternal conditions and its evolution over time.

2.1.2 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.[10] A small number of hospital based studies from the late 1920s offer detailed information on incidence and duration of the most common ailments. We use this evidence to construct a measure of the burden associated with maternal conditions.

Our measure is based on the concept of years lost to disability (YLD) developed by the World Health Organization (WHO):

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

[9] Weil (2007) offers an excellent discussion and review of the literature on the impact of health on productivity.

[10] The World Health Organization estimates that even today 42 percent of the women who give birth annually experience *at least* mild complications during pregnancy. Despite the large numbers of women who are affected by such morbidity, especially in developing countries, systematic measures of the economic impact of maternal conditions are not available (Holly, Koblinsky and Mosley, 2000).

where I is incidence and D represents duration. The variable DW, which stands for disability weight, is an index of the degree of disablement associated with a disease. A value of 0 stands for perfect health and 1 for death.[11] We interpret the YLD associated with each pregnancy as a time in which mothers would be unable to participate in the labor force.

Based on the hospital based studies from the 1920s, 12% of all live births generated some form of maternal morbidity (Kerr, 1933). Perineal lacerations from obstructed labor were the most debilitating and prevalent maternal condition, accounting for 67% of all cases of morbidity (or 8% of all live births). The duration of complaints ranged from seven months for rectovaginal fistula, to 3.5 years for other perineal lacerations and up to 7-13 years for prolapse of the uterus with an average duration of 55.67 months.[12] The WHO disability weight for rectovaginal fistula is 0.43. This is a relative large number, considering that the disability weight for blindness is 0.60 and the one for AIDS is 0.505. These conditions were prolonged but mostly temporary. Other conditions that were common give rise to severe and chronic disablement. For example, the disability weight for neurological sequelae of hypertensive disorders of pregnancy (corresponding to toxaemia and related conditions) is 0.38 in childbearing years and increases with age, reaching 0.468 at 60+ years of age. The disability weight for severe anaemia resulting from a maternal haemorrhage is 0.09 until the end of life. The disability weight for a healthy pregnancy is 0.22.

To calculate the total years lost to disability for maternal conditions, we combine the historical data on incidence and duration with the WHO age specific disability weights. We obtain two values, one for childbearing years (age 14 to 44, based on the WHO definition) and one for post-childbearing (age 44 to 60+).

$$
\begin{aligned}
YLD^{14-44} &= 1.17, \\
YLD^{44+} &= 1.09.
\end{aligned}
$$

This measure of YLD provides an estimate of the per pregnancy burden. To obtain the total burden for the temporary conditions, we have to adjust for the overall number of pregnancies. This is greater than the number of live births, and this difference is particularly important in early years due to the high incidence of stillbirths and neonatal deaths.

We measure the lifetime number of live births with the Total Fertility Rate (TFR), a widely used measure of completed fertility based on live birth registration data.[13] To estimate the corresponding number of pregnancies, we make two adjustments. The first corrects for measurement error, which was a serious issue in birth registration (Loudon, 1992). Specifically, we use the neonatal mortality rate at less than 1 week to measure under-registration.[14] The second adjustment estimates the number of pregnancies from the number of live births, corrected for measurement error. Specifically, we use the stillbirth rate to measure the probability of an unsuccessful pregnancy.[15] Letting n_t denote the neonatal death rate at less than 1 week in year t and s_t

[11] This data is collected as part of the Global Burden of Desease Study Program. See http://www.who.int/healthinfo/bod/en/index.html. Table A2 in the appendix reports this disability weights by maternal conditions.

[12] The Data Appendix reports the historical data as well as the calculations to obtain this estimate.

[13] See Jones and Tertilt (2007) for an extensive discussion of lifetime fertility measures.

[14] Since no guidelines were available, children that had died by the time of registration were often registered as stillbirths even if born alive and many births simply went unregistered. According to Woodbury (1926), births fell short of their true value by 8.7%. Our adjustment is quite conservative as it implies a 3% rate of under-registration in 1920.

[15] The stillbirth rate only includes fetal deaths in which the period of gestation was 20 weeks or more. See Data Appendix for details.

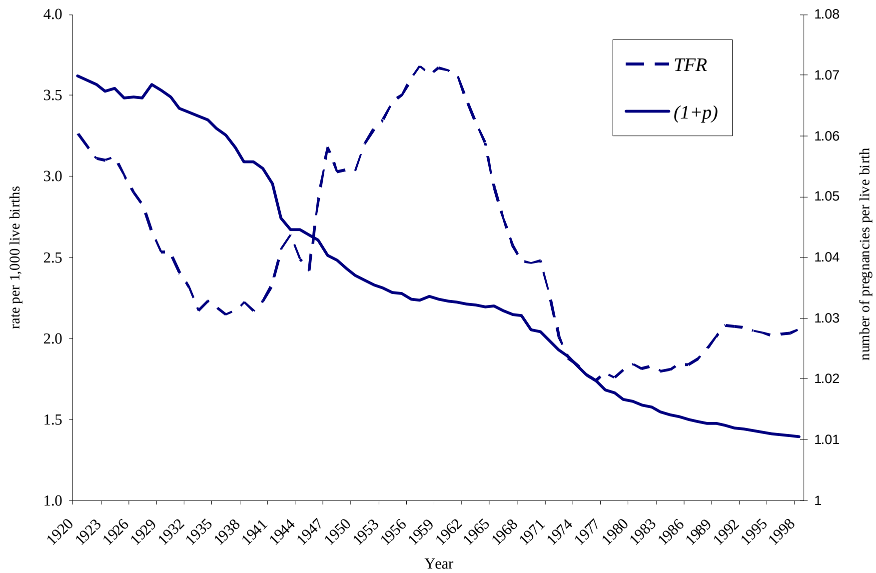

Figure 4: Completed Fertility (TFR) and Number of Pregnancies per Live Birth $(1 + p)$.

the stillbirth rate, the number of pregnancies for each live birth is $(1 + p_t)$, with $p_t = n_t + s_t$, and $P_t^* = TFR_t * (1 + p_t)$ for completed fertility. Many of the stillbirths and neonatal deaths were caused by maternal conditions, especially toxaemia and obstructed labor, so the resulting adjustment is quite significant for the early years. In 1920, each live birth was associated with 1.07 pregnancies. This implies that while the TFR was 3.26, the number of pregnancies equaled 3.55 in 1920.

The advances in reproductive medicine led to a decline in the burden of maternal conditions. We construct a time series of this burden based on the evolution of maternal mortality. The implicit assumption is that maternal disability declined at the same rate as maternal mortality.[16] Our estimated time series for the lifetime burden of maternal conditions per pregnancy during and beyond childbearing years is:

$$\begin{aligned} \bar{b}_t &= YLD^{14-44} \times \tilde{M}_t, \\ \underline{b}_t &= YLD^{44+} \times \tilde{M}_t, \end{aligned} \qquad (1)$$

where $\tilde{M}_t = MM_t / MM_{1920}$ and MM_t is the maternal mortality rate in year t.

Figure 5 plots $\tilde{M}_t$, while Figure 4 displays TFR_t and $(1+p_t)$. The time series for b_t are plotted in Figure 8. Both the decline in maternal mortality and the reduction in stillbirths alleviate the burden associated with maternal conditions. Stillbirths declined from 4% of live births in 1930 to 2% in 1953, a trend driven by improved pre-natal care (O'Dowd and Phillipp, 1994) and a fall in the incidence of obstructed labor. The number of pregnancies per live birth drops from 1.07 in 1920 to 1.01 in 1950. Thus, $(1 + p_t) * \tilde{M}_t$ can be taken as an index of progress in maternal health.

[16] Obviously this is not ideal but, given the absence of time series data on maternal morbidity, we think that this is a reasonable assumption.

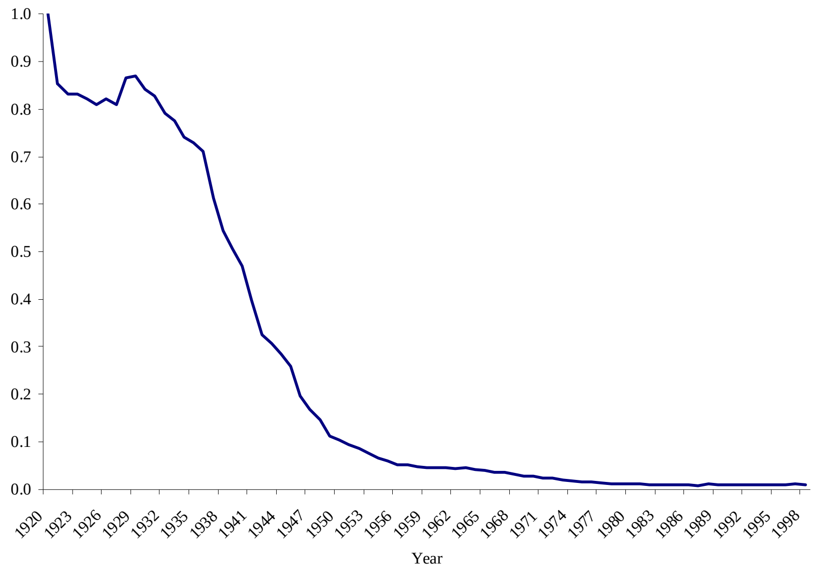

Figure 5: Evolution of maternal mortality, $\tilde{M}_t$

2.2 Advances in Infant Feeding

Until the early decades of the 20th century, most infants were breast fed. The only two alternatives were wet nurses or cows' milk. By the end of the 19th century, both these options were deemed inadequate.[17] 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 in the major urban areas were undertaken with the purpose of reducing infant and child mortality from gastrointestinal diseases[18]. Efforts to develop a substitute for breast milk for infants whose mother had died spurred commercial and scientific interest in the development of infant formulas, even as breast feeding was prescribed as the best practice.

The discovery that cow's milk is a very poor alternative to human milk constituted a significant breakthrough in infant nutrition.[19] The first chemical analysis of cow's milk in 1838 revealed that it was too high on proteins and too low on fat and carbohydrates relative to human milk. This discovery led to the first generation of cow's milk modifiers, such as Leibig's, Nestle's and Mellin's infant food, introduced commercially between the 1870s and the 1890s. These products contained

[17] After a failed attempt to regulate wet nursing by instituting certified directories in the late 19th century, concerns about transmission of siphylis and other deseases led to its virtual disappearance by the mid-twentieth century. See Golden (1996) for more details.

[18] The first federal law on the purity of food supplies was passed in 1906. The establishment of Children Bureau in 1912 strongly contributed to the furthering of this agenda. By 1920, milk pasteurization had become the norm in most states, and by 1940 most metropolitan areas had developed sources of untainted drinking water and sewage disposal systems. See Wolfe (2001). These developments were a necessary condition for the diffusion of water based infant formulas.

[19] See Packard and Vernal (1982), Apple (1987) and Schuman (2003) for a detailed account of the history of infant formula in the United States.

a combination of malt, wheat flour and sugar to be mixed with hot cow's milk, and were strongly opposed by pediatricians who worked to develop more scientific methods for modifying cow's milk. The most successful was Rotch's "percentage method," the medical gold standard for infant feeding between 1890 and 1915. This formula was so complex that it was mostly prepared in milk laboratories and distributed through pediatricians.

The most important innovation in infant feeding occurred in the early 1920s when two pediatricians succeeded in creating a water based infant formula that exactly reproduced the content of fat, proteins and carbohydrates in maternal milk. The first 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 human milk and more convenient for mothers.[20]

2.2.1 Changes in Breast Feeding Practices

The introduction of effective and easy-to-prepare infant formulas induced a remarkable shift from breast to bottle feeding starting in the 1930s. We rely on several sources to document this phenomenon, including in-depth studies of US localities in the 1910s and hospital discharge records. The details on the data sources and the construction of the series are described in the Data Appendix, Section 6.7.

Figure 6 displays the trend in incidence and duration of breast-feeding. We report information on in-hospital partial and exclusive breast-feeding rates,[21] and on breast-feeding rates at 6 months. Until 1930 over 90% of newborns were breast fed. This fraction declined precipitously over the next few decades. By 1956, the in-hospital breast-feeding rate had dropped to 37%, further declining to 25% by 1971. The decline was greater for exclusive breast-feeding rates and at longer breast feeding durations. The in-hospital exclusive breast-feeding dropped from 88% in 1920 to 21% in 1956 where it hovered until 1970. The percentage of infants breast fed at six months also dropped substantially - from 74% in 1920 to 3.4% by 1971. The dramatic change in breast-feeding practices occurred across all socioeconomic and demographic groups and independently from the labor force status of the mother (see Hirschman and Butler, 1981.)[22]

The evidence on trends in the use of commercially prepared formulas is only available since the 1950s. The fraction of infants who were fed commercial formulas at 1 week of age increased from 23% in 1955 to 77% in 1971 (Martinez and Nalezienski, 1979.) The fraction of 2 to 3 month-old infants fed on commercial formulas increased from 30% in 1958 to 70% in 1970 (Fomon, 2001.)

The incidence of breast feeding increased substantially between 1975 and 1983 owing to new medical findings on the immunization properties of human milk, as well as a series of highly publicized cases of metabolic dysfunction linked to infant formulas.[23] After a decline during the second half of the 1980s, breast-feeding rates continued to rise steadily.[24] However, the increase

[20] The name Similac was proposed by Morris Fishbein, the editor of the Journal of the American Medical Association in the 1920s (Schuman, 2003).

[21] For 1918 the "in-hospital" figures refer to babies breast fed before 1 month of age. The "exclusive" breast-feeding rate includes children who are fed only human milk. The breastfeeding rate includes infants who receive a combination of breast milk and formula.

[22] For example, they document that between 1950 and 1970 breast-feeding rates declined both for working and for non-working mothers, although non-working women were more likely to breast feed for more than 3 months.

[23] These cases prompted the passage of the Infant Formula Act of 1980 which established standards for many nutrients in formulas and mandated extensive testing (Schuman, 2003.)

[24] The diffusion of breast pumps likely contributed to this trend. Although rudimental breast pumps existed since the 16th century, the first successful mechanical pump for humans was introduced in

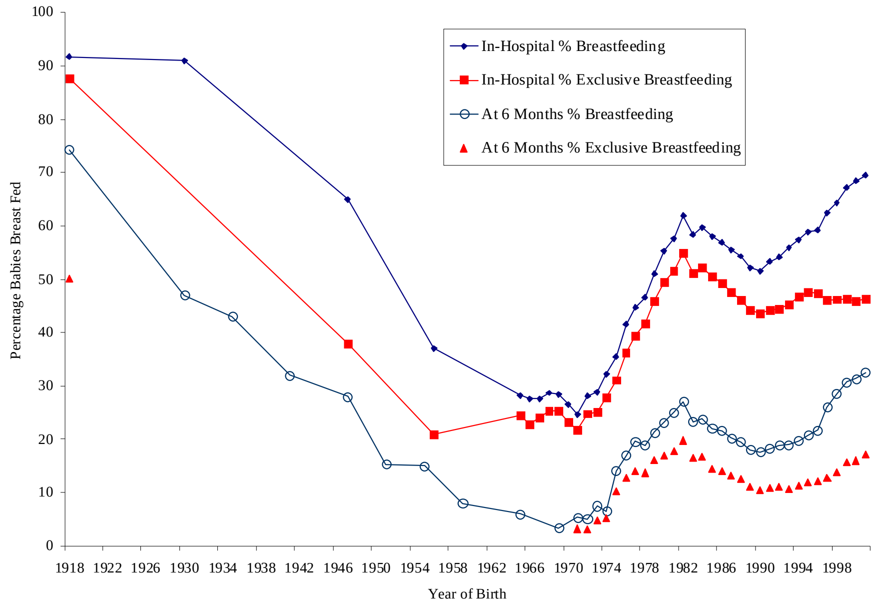

Figure 6: Trends in incidence, duration and exclusivity of breastfeeding

occurred mostly for in-hospital breast feeding rates. Exclusive breast feeding and its duration remains substantially lower today than they were in the early decades of the 20th century.[25]

2.2.2 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.[26] 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.

Figure 7 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 commercial formulas were fed Similac (see Table III in Fomon, 1975.)[27] The value of 2 for the time price in 1935 means that the cost of 1 liquid ounce

1956. The development of light and efficient portable breast pumps occurred in the early 1990s. See http://www.slate.com/id/2138639/#ContinueArticle.

[25] Evidence from the 2002 National Immunization Survey confirms these trends (see Li, Darling, Maurice, Barker and Grummer-Strawn, 2005).

[26] 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.

[27] SMA did not achieve great popularity in the U.S, and in 1975 it accounted for less than 12% of the market for commercially prepared formulas (Fomon, 1975). Enfamil, was launched in 1959.

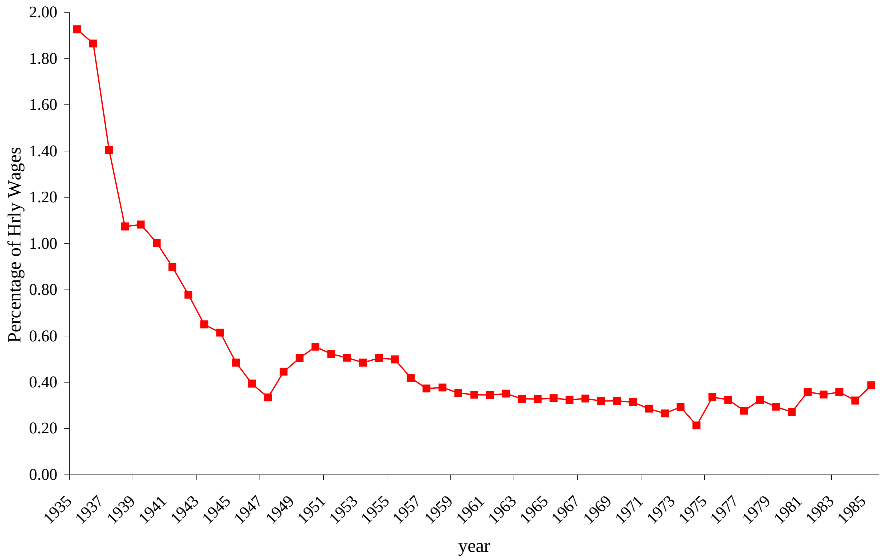

Figure 7: Time Price of Similac

of Similac corresponds to 2% of the hourly wage in manufacturing in that year. 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 reduction in the total cost of bottle feeding. Table 1 summarizes the average monthly cost of bottle feeding in 1936, expressed in 2000 USD. The calculations account for the variation by weight and age of the quantity of formula required. See the Data Appendix for the details. The total cost of bottle feeding a boy of median weight during the first year of life in 1936 ranged between $340-455, corresponding to 6-10% of average yearly income of white, male, full time year round salaried workers.[28] By 1960, this cost had fallen to less than 1.5% of average yearly labor income.

Table 1. Estimated cost of bottle feeding in 1936

	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

[28] Labor income is for 1939. See section 6.2 for details.

The decline in the time price of infant formula between 1935 and the mid 1950s may explain the large drop in breast feeding rates over the same period. The potential impact of the availability and diffusion of infant formula on mother's time-use is very significant. First, breast feeding is a time intensive activity. Based on accounts from pediatric journals, the average time spent for each feeding ranges from 20 to 30 minutes. Given the number of required daily feedings by age, the total feeding time for a child in the first year of life totals 700 to 900 hours, corresponding to an average 13.6 to 17.3 hours per week of mother's time, a very considerable fraction of a 40 hour workweek. This estimate is consistent with historical time use evidence in Brossard (1926) and Wilson (193-), who report that infant feeding added 15 and 17 hours of home production, respectively.[29] Additionally, infant feeding needs to be administered at specific times.

The diffusion of infant formula does not 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.

3 Theory

The economy is populated by overlapping generations of agents who differ by intrinsic labor productivity, ξ, and gender, $j = f, m$. Each cohort lives for $L > 2$ periods and is split equally by gender. The distribution of labor productivity is the same across genders. All agents belong to a household which comprises one male and one female. Household preferences are defined over household consumption, c, and individual leisure, l^j for $j = f, m$, and are represented by the following lifetime utility function:

$$\sum_{r=1}^{L} \beta^{r-1} u\left(c_r, l_r^f, l_r^m\right),$$

where

$$u\left(c, l^f, l^m\right) = c + \sum_{j=f,m} v\left(l^j\right).$$

The function $v(\cdot)$ is continuous, twice differentiable, strictly increasing and strictly concave. The parameter $\beta \in (0,1)$ represents the per period discount factor.

Leisure is defined as:

$$l = T - p\bar{n} - h,$$

where T is the individual time endowment, $p \in [0,1]$ denotes the fraction of time spent in the labor force, $\bar{n}$ is the fixed number of work hours if employed, and h denotes home hours.

Home hours are applied to the production of two goods, an *infant good*, I, and a *general home good*, G. Infant good production corresponds to activities connected to the presence of infants in the household. The time required for infant good production includes the time commitment

[29] The study of professional women in the Washington D.C. area in Brossard (1926) suggests that an infant would add a minimum of 15 hours of home production 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.

associated with pregnancy, childbirth and the burden of maternal conditions, as well as infant feeding. General home goods correspond to the usual notion of home production, that is chores such as meal preparation, cleaning, yard work and so on. We do not model preferences for home goods and simply assume that their level of production is exogenously given[30] and generates a demand for inputs, specifically home hours, that in turn depends on the choice of production technology. We now describe this framework in detail.

3.1 Infant Goods

The time required for infant good production comprises two components. The first, denoted with b, includes the time for pregnancy, childbirth and post-partum disabilities, which we take to correspond to the burden of maternal conditions. The second component, denoted with f, represents the time required for infant feeding.

The component b is taken as given by the household and varies with age:

$$b_r = \begin{cases} \bar{b} \text{ for } 1 \leq r \leq L_I, \\ \underline{b} \text{ for } L_I < r \leq L. \end{cases} \tag{2}$$

The years in the range $\{1, 2, ...L_I\}$ correspond to the fecund period of life in which childbearing occurs. The component f also varies by age:

$$f_r = \begin{cases} \phi \text{ for } 1 \leq r \leq L_I, \\ 0 \text{ for } L_I < r \leq L, \end{cases} \tag{3}$$

since infants are only present during childbearing years. The values of $\{\underline{b}\ , \bar{b}\}$ and f will be calibrated based on the evidence in Section 2.1.2 and 2.2.

We assume that households choose the technology for infant feeding. The variable $\tau_r^I \in [0, 1]$ corresponds to this choice. If $\tau_r^I = 0$, infants are exclusively breast fed, whereas if $\tau^I = 1$, infants are exclusively bottle fed. If τ_r^I is interior, households choose a combination of breast and bottle feeding. There is no monetary cost associated with breast feeding, while q^I is the cost of exclusive bottle feeding, which corresponds to the expense for the required infant formula. Therefore, household expenditure on bottle feeding is $q^I \tau^I$.

The total demand on the wife's time for infant good production at age $r \leq L$ is given by:

$$h_r^{fI}\left(\tau_r^I\right) = b_r + \left(1 - \tau_r^I\right) f_r > 0. \tag{4}$$

While bottle feeding reduces the time devoted to infant good production by the wife, we assume that it increases the time required for general home good production, since it can be equivalently carried out by the wife or the husband, as we describe below.

3.2 General Home Goods

Let H denote the labor required for general home production. Spouses contribute according to:

$$H = \left[\left(h^{fG}\right)^{\zeta} + \left(h^m\right)^{\zeta}\right]^{1/\zeta}, \tag{5}$$

[30] We will make this level depend on the number of children in the quantitative exercise.

where $\zeta \in [0,1]$ and $1/(1-\zeta)$ is the elasticity of substitution between the husband's and wife's time. Their contribution is symmetric, as represented by the equal weighting in (5).

The level of H depends on the technology used for general home production and, in childbearing years, for in infant feeding. The choice of technology for general home production is denoted with $\tau^G \in [0,1]$, where $\tau^G = 0$ denotes the "old technology" and corresponds to fully manual general home production, while $\tau^G = 1$ corresponds to a mechanized "new technology" that relies on home appliances. For households in their childbearing years, the time needed for bottle feeding is also included in the time required for general home production. Thus, the demand for labor in general home production is given by:

$$H_r\left(\tau^G, \tau^I\right) = g_O\left(1-\tau_r^G\right) + \tau_r^G g_N + \tau_r^I f_r, \tag{6}$$

for $r = 1, 2, ..L$. Here, g_N and g_O with $g_N < g_O$ represent the time that must be devoted to chores under the new and old, respectively, technology for general home production. The old technology only requires labor input, while the new technology also requires market goods, specifically home appliances. We denote with q^G the relative price of home appliances associated with the new technology. The corresponding household expenditure on these goods is $\tau_r^G q^G$.

We now describe the household's problem.

3.3 Household Problem

Spouses have the same level of intrinsic labor productivity ξ. Their wages also depend on a pre-marital labor market investment, denoted with $e \in [0,1]$. This investment should be interpreted broadly, as any action or decision that serves to increase lifetime earnings, including formal education, pre-marital labor market experience, occupational training and so on. The parameter $\varepsilon^j > 0$ represents the initial returns to pre-marital investment and is allowed to be gender specific, consistent with empirical evidence.[31] We allow for these returns to depreciate over time at a rate that is inversely related to cumulated labor force participation. This implies the following wage function for an agent with intrinsic productivity ξ:

$$w_r^j(\xi) = \xi\left(1 + \varepsilon^j \delta^{\sum_{s=1}^{r-1}\left(1-p_s^j\right)} e^j\right), \tag{7}$$

for $j = f, m$ and $r = 1, 2, ..L$. The parameter $\delta \in (0,1)$ corresponds to the geometric rate of depreciation. If an agent's participation is equal to one in all prior periods, her wage at age r is simply: $\xi\left(1+\varepsilon e^j\right)$. If the agent temporarily drops out of the labor force, the wage depreciates at rate δ. This feature of the model captures the concavity of the wage profile over the life cycle documented in Goldin (1989) and Eckstein and Wolpin (1989) and is consistent with our interpretation of pre-marital investment to include work experience.

Investment in market skills induces a utility cost, represented by $c(e)$, where $c(\cdot)$ is a twice continuously differentiable, strictly increasing and convex function. Since men's participation rate is one in all periods, the wife/husband ratio of wages within a household is $w_r^f/w_r^m = \xi\left(1+\varepsilon\delta^{\sum_{s=1}^{r-1}\left(1-p_s^f\right)} e^f\right)/\left(1+\varepsilon e^m\right)$, and depends on the wife's experience, as well as her pre-marital labor market investment.

[31] See Section 4.1.

Households take as given the lifetime path of infant formula $\left\{q_r^I\right\}_{r=1}^{L_I}$ and the lifetime path of home appliances $\left\{q_r^G\right\}_{r=1}^{L}$. Their intertemporal budget constraint is:

$$\sum_{r=1}^{L} \frac{\left(c_r - \sum_{j=f,m} w_r^j p_r^j\right)}{(1+R)^r} + \sum_{r=1}^{L} \frac{\tau_r^G q_r^G}{(1+R)^r} + \sum_{r=1}^{L_I} \tau_r^I q_r^I \leq 0. \tag{8}$$

Thus, substituting this constraint in the utility function yields the following problem for the household:

$$\begin{aligned} V \quad = & \max_{\{\tau_r^I\}_{r\leq L_I}, \left\{e^j, p_r^j, h_r^j, \tau_r^G\right\}_{r\leq L}^{j=f,m}} \sum_r \beta^{r-1} \frac{\sum_{j=f,m} w_r^j p_r^j - \tau_r^G q_r^G}{(1+R)^{r-1}} - \sum_{r\leq L_I} \beta^{r-1} \frac{\tau_r^I q_r^I}{(1+R)^{r-1}} \\ & -c\left(e^f\right) + \sum_r \beta^r \left[\sum_{j=f,m} v\left(T - p_r^j \bar{n} - h_r^j\right)\right] \end{aligned}$$

subject to (4), (2), (3), (5), (6), (7), $h_r^f = h_r^{fI} + h_r^{fG}$, $h_r^{fI} = 0$ for $r > L_I$. For simplicity, we set $e^m = 1$ and $p_r^m = 1$ for all r. That is, all husbands invest in labor market skills before marriage and participate to the labor market in each period.

3.4 Market Production and Equilibrium

At each date t, a continuum of identical, perfectly competitive firms produce consumption goods, C, infant formula, K_I, and home appliances, K_G, and according to the technology:

$$\theta_t^I K_{I,t} + \theta_t^G K_{G,t} + C_t \leq N_t, \tag{9}$$

where θ_t^l for $l = I, G$ are the marginal rates of transformation between consumption and the goods used in home production. The variable N_t corresponds to per capita aggregate labor supply in efficiency units given by:

$$N_t = \bar{n} \sum_{r=1}^{T} \sum_{j=f,m} \int_\xi p_{r,t}^j(\xi)\, w_{r,t}^j(\xi)\, d\Gamma(\xi), \tag{10}$$

where $p_{r,t}^j(\xi)$ and $w_{r,t}^j(\xi)$ denote labor force participation and effective productivity, respectively, of an individual of age $r = 1, ..L$, gender $j = f, m$ and productivity ξ at date t.

Let $\bar{w}_t$ correspond to the average economy-wide wage at date t, given by:

$$\bar{w}_t = \sum_{r=1}^{T} \sum_{j=f,m} \int_\xi w_{r,t}^j(\xi)\, d\Gamma(\xi). \tag{11}$$

Firm optimization implies that (9) holds with equality and that for $l = I, G$:

$$q_t^l / \bar{w}_t = \theta_t^l, \tag{12}$$

for all t. Thus, θ_t^I and θ_t^G correspond to the relative price, or *time price*, of infant formula and home appliances at date t.

Definition 1 *A date t equilibrium is an allocation* $\left\{p^j_{r,t}(\xi), e^j_{r,t}(\xi), h^j_{r,t}(\xi)\right\}^{j=f,m}_{r\leq L}$, $\left\{\tau^G_{r,t}(\xi)\right\}_{r\leq L}$, $\left\{\tau^I_{r,t}(\xi)\right\}_{r\leq L_I}$ *such that for given* $\left\{q^I_t, q^G_t, R_t\right\}_t$, *the allocation solves the household problem for all households* $\{r, \xi\}$, *firms maximize profits, and the markets for infant formula, home appliances and consumption clear.*

The sequence of interest rates $\{R_t\}_t$ is exogenous in the model. The demand for K_I, K_G is a function of the pattern of technology adoption. Bottle feeding and adoption of the new general home technology generate a demand for a fixed quantity of formula and home appliances that varies linearly with the rate of adoption. The linearity of preferences in consumption and linearity of the production technology ensure that the time price of the market goods used in home production does not depend on the level of demand.

3.5 Skills, Participation and Home Hours

This framework is parsimonious, yet it is sufficiently rich to allow for an endogenous allocation of home hours across spouses and an endogenous gender wage differential. This is a significant step forward relative to standard macroeconomic models of household decisions that simply assume a particular pattern of home hours by gender or treat gender earnings differentials as a parameter.

We now analytically derive some key properties of the model from the solution to the household problem and illustrate the mechanism through which medical progress influences household decisions.

The first order necessary conditions for effort and participation for $\delta = 1$ are:

$$\sum_r \beta^{r-1} p^j_r \varepsilon^j \xi - c'\left(e^j\right) \leq 0, \tag{13}$$

with equality at $e^j \in (0,1)$,

$$\xi\left(1 + \varepsilon^j e^f\right) - \bar{n} v'\left(T - p^f_r \bar{n} - h^{fI}_r\left(\tau^I_r\right) - h^{Gf}_r\right) \leq 0, \tag{14}$$

for $j = f, m$ with equality at $p^j_r > 0$.

Equation (13) clearly shows that pre-marital investment in market skills increases with lifetime participation by the convexity of $c(\cdot)$. Similarly, by equation (14) and the concavity of $v(\cdot)$, participation is increasing with investment in market skills, generating a positive complementarity between pre-marital investment and participation. Equation (14) also implies that participation is decreasing in the burden of maternal conditions and the time devoted to infant feeding, for a given the wage.

The time devoted to infant good production by the wife at age r depends on b_r as well as on the choice of infant feeding technology. The evidence in Section 2.1.2 suggests that $\bar{b} > \underline{b} > 0$, since the burden of maternal conditions is greater in childbearing years and certain maternal conditions are chronic. By (2) and (3), women's participation will be lower in childbearing years than post-childbearing, and even in post-childbearing years will be lower than men's, consistent with the data.

The condition that pins down the allocation of home hours devoted to general home production depends on the labor market behavior of the wife. If she is in the labor force, that is $p^f_r > 0$, the allocation of home hours depends on the couples' relative wages:

$$\left(\frac{h_r^{fG}}{h_r^m}\right)^{\zeta-1} = \frac{\left(1+\varepsilon^f e^f\right)}{\left(1+\varepsilon^m\right)}, \tag{15}$$

for $\delta = 1$. Then, if the wife's wage is lower than the husband, $e^f < e^m$, she will have greater home hours, $h_r^{fG} > h_r^m$. If the wife does not participate, $p_r^f = 0$, equation (14) implies:

$$\left(\frac{h_r^{fG}}{h_r^m}\right)^{\zeta-1} = \frac{v'\left(l_r^f\right)}{v'\left(l_r^m\right)}. \tag{16}$$

Thus, a particularly low value of the wife's leisure, for example during childbearing years, tends to increase the husband's home hours.

These equations clearly identify the mechanism through which medical progress influences women's pre-marital investment in market skills, participation and home hours in the model. The advances in reproductive medicine lead to a reduction in the burden of maternal conditions, that is a decline in b_r. Progress in infant feeding corresponds to a decline in the time price of infant formula, θ_t^I, and induces households to adopt bottle feeding. These factors have a positive direct effect on married women's participation during childbearing years. This in turn increases women's pre-marital investment in market skills raising their wage relative to their husbands. As a consequence, married women's participation rises in all stages of the lifecycle, their contribution to general home production also declines, and their earnings relative to men rise[32].

We now evaluate the quantitative relevance of this mechanism.

4 Quantitative Analysis

To quantitatively evaluate the impact of progress in reproductive medicine and infant feeding on married women's labor force participation, we calibrate the model to match key statistics on labor force participation, infant feeding, home production and gender earnings differentials in 1920, and then simulate the model between 1920 and 1995, feeding in the historical evolution of the burden of maternal conditions, the time price of infant formula, the total fertility rate, as well as the time price for home appliances. We examine the effect of these factors jointly, and then we run several counterfactual simulations to assess the contribution of each of these forces in isolation.

We begin by describing our calibration strategy in detail.

4.1 Calibration

We make the following assumptions on functional forms. The utility from leisure and the disutility of effort are given respectively by:

$$v(l) = \psi_0 \frac{l^{1-\psi}}{1-\psi},$$

with $\psi_0, \psi \geq 0$,

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

[32]Given that the production technology is linear in labor input, the entry of women into the labor force does not affect labor demand. As women invest in labor market skills and enter the labor force average productivity and economy-wide output rise.

with $\gamma_0 > 0$ and $\gamma < 0$. The distribution of ξ is log-normal, with mean $\bar{\xi}$ and standard deviation σ_ξ.

The model has sixteen parameters: β, ψ_0, ψ, $\bar{n}$, γ_0, γ, $\varepsilon^f, \varepsilon^m$, δ, b, f, ζ, g_O, g_N, $\bar{\xi}$, σ_ξ. In addition, the equilibrium in 1920 also depends on the lifetime path for the time price of infant formula, $\{\theta_r^I\}_{r=1}^{L_I}$, and home appliances, $\{\theta_r^G\}_{r=1}^{L}$, confronted by all agents alive in 1920, as well as on the interest rate R. We set the yearly discount and interest rates to 5%, which implies $\beta = 1/R = 0.78$.

The remaining parameters are estimated based on historical evidence or chosen to match the value of key statistics for the U.S.A. in 1920, including participation of married women, home hours by gender, breast feeding, diffusion of home appliances and gender earnings differentials. The resulting values of all parameters are presented in Table 3. The data used for the calibration are described in detail in the Data Appendix.

4.1.1 Demographics, Preferences and Wages

The demographic parameters are set to match childbearing behavior. Specifically, agents enter the model at age 23, the median age of first birth in 1920. The childbearing stage of life ends at age 33, which corresponds to the age of last birth in 1920. The years between age 34 and 63 correspond to the post-childbearing stage of life[33]. We assume that the model period corresponds to five calendar years, so that $L_I = 2$ and $L = 8$.

The labor supply parameters are set as follows. The total time endowment T is normalized to 1, and $\bar{n}$ is set to 40/112, based on a 40 hour work week and 112 hours of active time per week. The parameter ψ is set to match a Frisch elasticity of labor supply for men equal to 0.1. This delivers $\psi = 17.25$ and implies that married women's Frisch elasticity in the model is 0.25 in 1970. These values are well within the range reported in Blundell and MaCurdy (1999).

We set the returns to pre-marital investment in market skills based on the estimated returns to labor market characteristics in Goldin (1990).[34] Specifically, we assume that an agent that has made a pre-marital investment in market skills in the model corresponds to a worker with twelve years of schooling, a high school degree and five years of work experience who is married, in the data. Based on the returns to each of these characteristics, we obtain $\varepsilon^m = 0.86$, $\varepsilon^f = 0.61$. Thus, the return for married women is 70% of the male return. We set the elasticity of pre-marital investment in market skills to lifetime participation to 1, which implies $\gamma = -0.5$ given our calibrated value of δ.

4.1.2 Infant Good

We set the burden of maternal conditions in the model based on the approach discussed in Section 2.1.2. The WHO disability weights are available for ages 15-44 and 45-59 and 60+. Thus, we correspondingly allocate the WHO burden for specific ages across the childbearing and post-childbearing years in the model. We adjust for the number of pregnancies, using the series, p_t, described in Section 2.1.1. For all temporary maternal conditions in childbearing years, we multiply the corresponding weight by the number of pregnancies. We omit this adjustment for chronic conditions specific to post childbearing years. Table 3 plots the resulting values for the

[33] Female life expectancy at age 20 was 46.5 years in 1920.

[34] We use estimates in Table 4.3 and Figure 4.3.

per pregnancy burden of maternal conditions in each stage of the life cycle as a fraction of the time endowment.

For the parameters related to infant feeding, we proceed as follows. The time required for infant feeding, f, is set to 15 hours per week for one year per child, based on the evidence discussed in Section 2.2.2. This value is then multiplied by the number of live births, measured by the cohort total fertility rate. We set the level of the time price of infant formula in 1920 to match the average cost of feeding one child of median weight with infant formula for one year as a percentage of yearly male labor earnings (see Section 2.2.2), equal to 6%. This value is then multiplied by the number of live births to obtain household expenditures on infant formula. The time series of the time price of Similac described in Section 2.2.2 is used to compute the lifetime path of the time price of infant formula in the model.

4.1.3 General Home Production

The parameter ζ, which determines the degree of complementarity in the spouses' contribution to home production is set to match the optimal allocation of home hours for two earner households, which in the model is pinned down by equation (15). Specifically, we use home hours for ever married employed women and employed men ages 18-64 from Ramey (2009), and use the female/male wage ratio of hourly wages in manufacturing from Goldin (1990) as a measure of the wife/husband wage ratio. This yields: $\zeta = 0.7711$.

Finally, we set $g_N/g_O = 0.5$. This implies that adoption of home appliances induces a 50% reduction in the time required for general home good production. This is consistent with evidence on home hours for housewives and working married women, under the assumption that the latter adopted home appliances. We proxy the time price of home appliances in the model with the real value of the quality-adjusted Divisia price index for eight appliances built by Gordon (1990), rescaled by the real hourly wage in manufacturing. The initial value of this time series is calibrated as described below.

The remaining free parameters are ψ_0, γ_0, δ, g_O, $\bar{\xi}$, σ_ξ, and the level of the time price for home appliances in 1920, θ^G_{1920}. These parameters are calibrated to minimize the distance between the model prediction and the empirical counterpart for seven statistics. These are the average adoption rate of home appliances (based on the average percentage of households with washing machines, refrigerators and vacuum cleaners), the average in hospital bottle feeding rate, measured as one minus the in hospital exclusive breast feeding rate (see Figure 6); married women's average home hours, home hours of men; the female/male ratio of average earnings (Goldin, 1990). Finally, we target the labor force participation of married women age 23-33 in 1920 (born in 1886-1895) and of the same women at age 34-63 (Goldin, 1990). Since the male participation is one in the model but smaller in the data, our target is the ratio of female to male participation in the data. The calibrated parameters are reported in Table 3. The target statistics and the corresponding model counterparts are reported in Table 4.

Table 3: Calibrated Parameters					
Exogenously Set		Based on Independent Evidence		Matched to Data Targets	
β	0.78	θ^I_{1920}	0.06	θ^G_{1920}	0.6
R	5%	ζ	0.77	ψ_0	$3.8000e-05$
Demographics		$\{\varepsilon^f, \varepsilon^m\}$	$\{0.61, 0.86\}$	γ_0	$2.6700e-04$
Childbearing	23-33	γ	-0.5	$\bar{\xi}$	0.6
Post Childbearing	34-63	ψ	17.25	σ_ξ	0.7
		$\{\bar{b}, \underline{b}\}$	$\{0.057, 0.038\}$ per child	δ	0.9
		f	0.0134 per child	$\{g_O, g_N\}$	$\{0.5, 0.25\}$

At the calibrated parameters, there is a very close fit between the model generated statistics and their empirical counterparts. However, the model has difficulty matching the low value of male home hours in the data for all parameterizations that deliver plausible outcomes for the other variables of interest. This suggests that the low level of male home hours in the data is driven by factors not included in the model. In Section 4.4, we discuss a number of additional forces that may have an impact on gender roles and on the distribution of home hours.

Table 4: Calibration Targets		
Population Statistic	Value in 1920	Model
Average adoption of home appliances	7%	7%
Average bottle feeding rate	12%	12%
Married women's LFP, childbearing years (divided by men's)	9%	9%
Married women's LFP, post childbearing (divided by men's)	13%	13%
Female/male hourly earnings ratio	13%	14%
Home hours of married women	52	50.4
Home hours of men	3	13.4

4.2 Transition

Our model features three sources of technological change: the improvement in maternal health, the decline in the time price of infant formula and the decline in the time price of home appliances. We are interested in identifying the role of each of these forces, as well as their combined effect, on women's labor force participation, home hours and earnings. Thus, we feed historical time series for the corresponding measures and the exogenous path of fertility[35] into the model and simulate the equilibrium over time. We examine the time period between 1920 and 1995. We first consider the full model, and then analyze the impact of fertility combined with each source of progress in isolation (Section 4.3). We also evaluate the quantitative impact of forces that influence participation but are not included in the model (Section 4.4).

The improvement in maternal health is comprised of three components in the model. The most important is the decline in the burden of maternal conditions, corresponding to (1), as discussed in Section 2.1.2. In addition, the decline in maternal mortality determines a rise in the female-male difference in life expectancy at age 20, as documented in Section 2.1.1. To capture this effect, the

[35] In the model, all households in the same cohort are assumed to have the same fertility, corresponding to the empirical value of the cohort fertility rate for women age 23-33 in a given year.

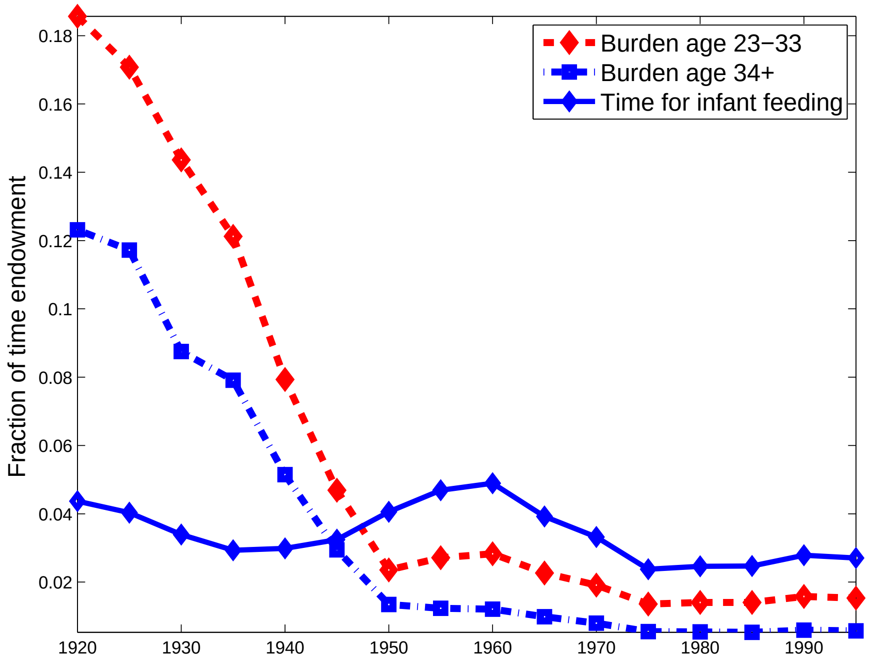

Figure 8: Burden of maternal conditions and time demand for infant feeding, adjusted for fertility.

length of the post childbearing phase in the model in adjusted to reflect the empirical increase in life expectancy. Finally, the number of pregnancies per live birth declines over time, thus, we feed in the variable p_t described in Section 2.1.2. We use the cohort fertility rate to adjust for the variation in number of live births over time.

The time series for expenditure on infant formula per child for exclusive bottle feeding is adjusted by the cohort total fertility rate to obtain the average expenditure per household. The time required for infant feeding f is also adjusted by the number of live births. Finally, we feed in the time series of the time price for home appliances used in the calibration to track progress in general home goods.

Figure 8 plots the burden of maternal conditions by age adjusted by the number of pregnancies and the time demand for infant feeding adjusted by the number of live births, expressed as a fraction of the time endowment[36]. The burden of maternal conditions at age 23-33 drops from 18% of the time endowment in 1920 to approximately 2% of the time endowment in 1965. The time demand for infant feeding is much smaller, ranging from 5% to 2.2% of the time endowment, depending on the number of live births. It is higher than the burden of maternal conditions starting in 1945.

Figure 9 displays the transitional dynamics predicted by the model in response to the exogenous evolution of fertility, maternal health, the time price of infant formula and the time price of home appliances. The improvement in maternal health includes the historical reduction of maternal mortality and corresponding effects on the burden of maternal conditions, the reduction of the number of pregnancies for each live birth as well as the rise in female life expectancy. In

[36] Figures 4 and 5 chart the values of TFR_t, p_t and $\tilde{M}_t$, while Figure 7 displays the series for θ_t^I that we feed into the model.

each panel, solid lines correspond to the predictions of the model and dotted lines correspond to the data. We report female participation by cohort, so that in any year the value of participation corresponds to participation at age 23-33 and at age 34+ of the women who are 23-33 years old in that year. For all other variables, we simply report cross-sectional yearly averages for the model as well as for the data[37].

The main findings from the transition in the full model are:

1. The model closely matches the empirical value of participation at age 23-33 between 1920 and 1935, while it overpredicts this outcome relative to the data between 1940 and 1965. The predicted value of female participation at age 34+ closely replicates the one in the data until 1960. The model underpredicts female participation at age 23-33 after 1980 and at age 34+ after 1970. In Section 4.4, we discuss and quantify the role of cultural, institutional and technological forces absent from our model that can account for these discrepancies.

2. The model overpredicts the female/male earnings ratio relative to the data after 1940. This is due in part to the fact that relative female participation at age 23-33 is higher in the model than in the data. This increases female earnings directly and indirectly, since it induces a rise in female wages at later ages. Moreover, we assume that the number of hours worked, conditional on participation, is not gender specific, whereas conditional on participation, married women's hours are smaller than married men's, especially in post-war years. Allowing for gender specific work hours would reduce the female/male earnings ratio in the model and bring it closer to its empirical counterpart.

3. The behavior of female (square marker) and male (diamond marker) home hours matches closely with their empirical counterparts, except that female home hours drop faster than in the data between 1945 and 1975. The convergence of female and male home hours over time stems from the rise in wives' relative earning potential due to medical progress, which induces greater symmetry in the household allocation of home hours. As a result, leisure for married men decreases over time, while leisure of married women rises. This prediction is consistent with empirical evidence for the US.[38]

4. The model replicates the inverted U-shape pattern of bottle feeding rates, though the peak in bottle feeding occurs later in the model, relative to the data. Moreover, the model predicts a slower initial rise in bottle feeding rates, relative to the data and predicts bottle feeding rates to be higher than in the data between 1975 and 1995. The decline in bottle feeding rates in the mid 1970s was in part due to new medical findings on the immunization properties of human milk and to a series of highly publicized cases of metabolic dysfunction linked to infant formulas, as discussed in Section 2.2. Since in our model, infant formula is deemed equivalent to breast milk and its quality is held constant throughout, we cannot capture this effect.

5. The model under predicts the diffusion of home appliances relative to the data. This is due to several factors. The demand for home appliances in the model depends on the burden of

[37] The model has rich cross-sectional predictions. For brevity, we limit ourselves to presenting aggregate and cohort outcomes.

[38] This phenomenon is discussed by Knowles (2005), who focusses on the time period 1965-2003. For our period of interest, it is not possible to measure home hours of husbands conditional on the participation of their wife. However, the downward trend in married men's leisure relative to their wife is clearly present. Knowles (2005) argues that this phenomenon can be explained by an increase of wives' bargaining power.

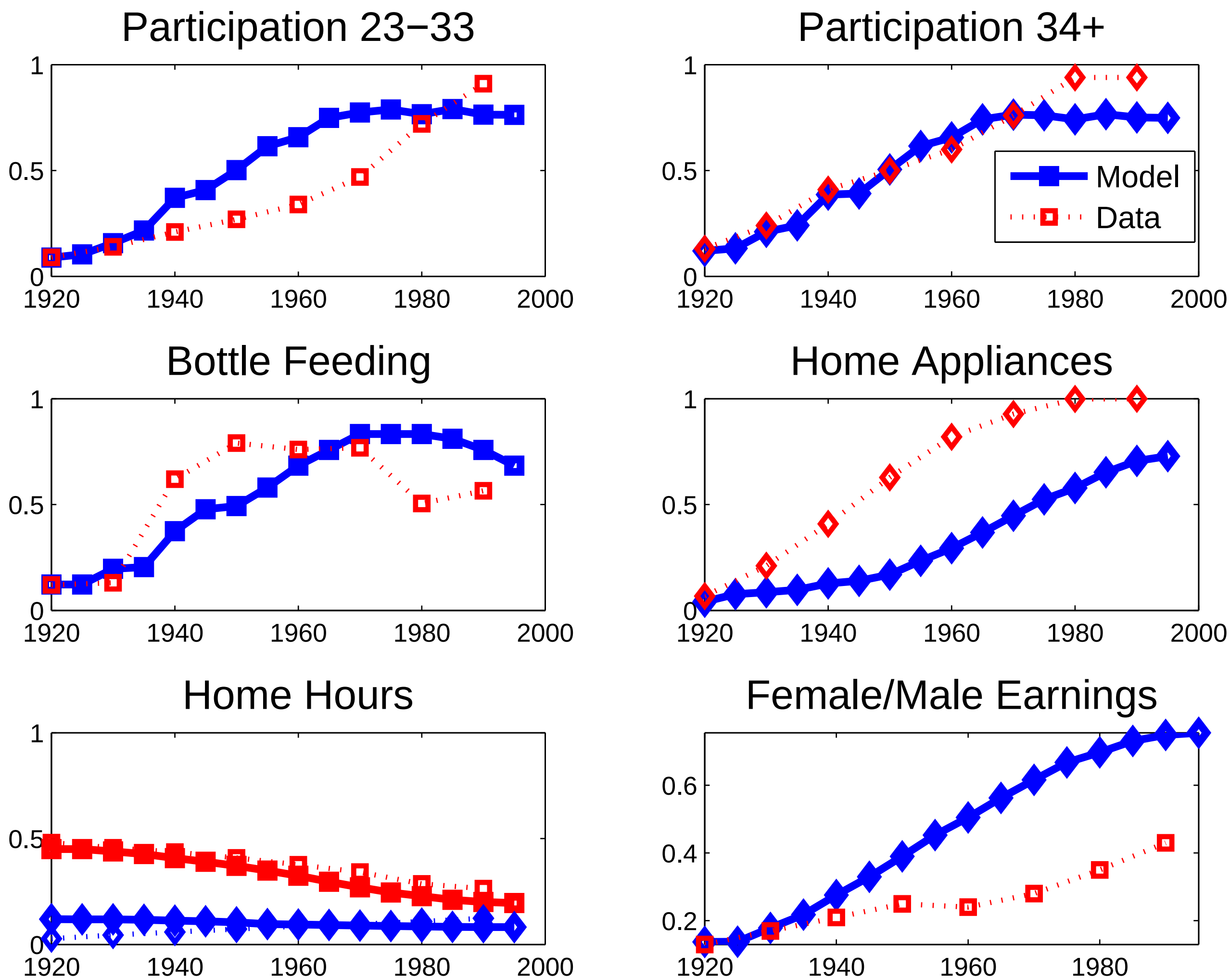

Figure 9: Predicted transition in full model.

maternal conditions, which imposes a very large constraint on women's time endowment in the early years of the simulation. As this burden is relaxed, the demand for home appliances endogenously falls for given price. This exerts an offsetting effect on the reduction in the time price on the demand for home appliances. In addition, we abstract from the dependence of the time required for general home production on the number of children (beyond the time for bottle feeding). Clearly, if we were to model this dependence, the Baby Boom would lead to a permanent increase in the demand for home appliances, since it would increase the time required for general home production at all ages, assuming children live within the household until at least age 18. Finally, the demand for general home production output is given in the model, while there is evidence it rises with income[39].

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

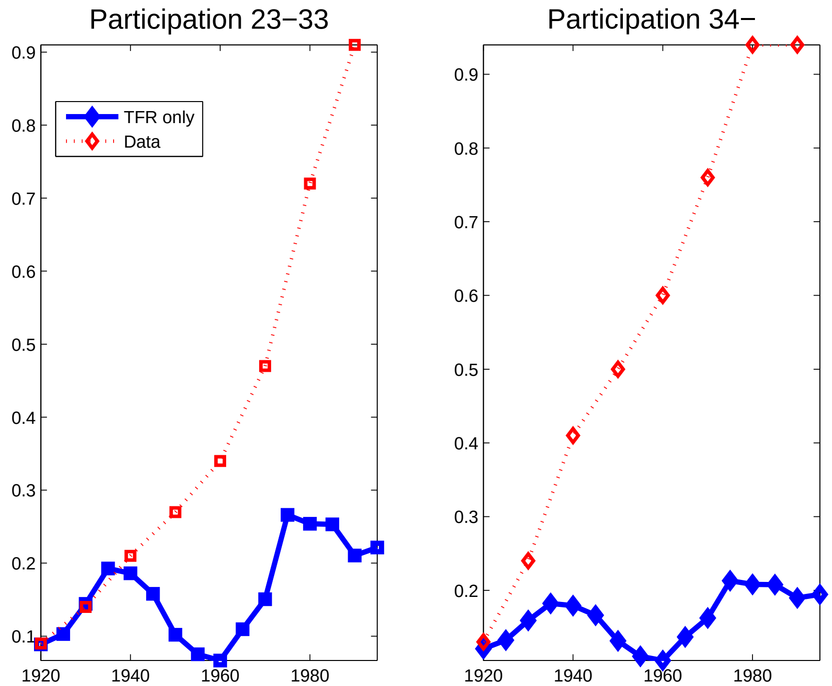

Figure 10: Predicted model transition with no sources of progress. Isolates the effect of fertility.

4.3 Experiments

To analyze the contribution of each force of progress in isolation, we run several counterfactuals. As a benchmark, we first simulate the transition in the model shutting down *all* sources of medical and technological progress. This leaves the historical path of the cohort total fertility rate as the only exogenously changing variable in the transition. The results are displayed in Figure 10.

This experiment clearly shows the strong impact of fertility on female participation at age 23-33. As the cohort total fertility rate drops from 3.26 in 1920 to 2.18 in 1935, participation at age 23-33 rises from 9% to 19%. The decline in fertility between 1920 and 1935 alone can fully account for the empirical rise in participation in childbearing years in this period. The onset of the Baby Boom, absent improvements in maternal health or infant formula, causes a reduction of female participation in childbearing years. As the total fertility rate rises from 2.23 to 3.65 between 1940 and 1960, participation at age 23-33 drops from 18.6% to 6.7%. Fertility affects participation beyond childbearing directly, via the burden of maternal conditions at age 34+, and indirectly, since low participation during childbearing years implies that women's wages are low post-childbearing. The effect at age 34+ is smaller that in childbearing years, but still quantitatively significant. Participation at age 34+ for women in childbearing years between 1920 and 1935 rises from 12% to 18%, and it drops from 18% to 10.4% between 1940 and 1965. Interestingly, the demand for home appliances is positively related to the number of live births. Adoption of home appliances rises from 11% in 1935, the trough of fertility in the pre-war years, to 21% in 1965, which corresponds to the peak of fertility in the data. This shows that the severe toll on women's time implied by the burden of maternal conditions combined with high fertility, generates a significant increase in the demand for home appliances.

We now analyze the effect of each source of progress in the model in isolation. A summary description of the experiments is provided in Table 5[40].

Table 5: Summary of Experiments	
Sources of Progress	Components
Full model	Medical Progress+ Progress in home appliances
Medical Progress	Improvement in maternal health+ Advances in infant feeding
Improvement in maternal health	Decline in burden of maternal conditions+
	Rising life expectancy+
	Reduction in number of pregnancies per birth
Advances in infant feeding	Decline in the time price of infant formula
Progress in home appliances	Decline in the time price of home appliances

4.3.1 Medical Progress

We now examine the joint impact of progress in maternal health and infant feeding. To do so, we shut down the decline in the time price of home appliances. Figure 11 displays the simulated transition for a version of the model.

The main finding is that progress in maternal health and infant feeding *alone* can account for the rise in participation at age 23-33 between 1920 and 1970, and at age 34+ between 1920 and 1945. The model over-predicts participation at age 23-33 between 1940 and 1965, as well as the rise in the ratio of female to male earnings after 1940, but to a smaller degree than the full model. The model now correctly predicts the timing of the initial rise and subsequent decline in bottle feeding rates, though predicts them to be approximately 20% lower than in the data at the peak. This outcome is in part due to the lack of progress in home appliances, which indirectly discourages adoption of infant formula, since infant feeding is a general home good when infant formula is used. The model closely matches the empirical behavior of female home hours.

4.3.2 Maternal Health

To examine the impact of advances in maternal health in isolation, we shut down the decline in time price of infant formula, in addition to progress in home appliances. Figure 12, Panels A and C, compares the path of participation by age in this version of the model, with the paths predicted by the version with no progress and the full version of the model, that is with progress in maternal health, infant feeding and home appliances. Improvements in maternal health alone determine a rise in participation at age 23-33 to 52% by 1970, the same value observed in the data for that year. Similarly, the predicted behavior of participation at age 34+ closely follows the corresponding empirical value until 1950, when it reaches a rate of 47%. Also, the comparison for the predicted behavior for the full model suggests that progress in maternal health accounts fully for the rise in participation at all ages in the model up to 1950. This force adds 27% to participation at age 23-33 and 18% at age 34+ for the cohort of women in childbearing years in 1960, that experiences the peak of fertility in the simulations. As for the full model, participation

[40] For each experiment, we feed in the historical series of the cohort total fertility rate to adjust for the number of live births.

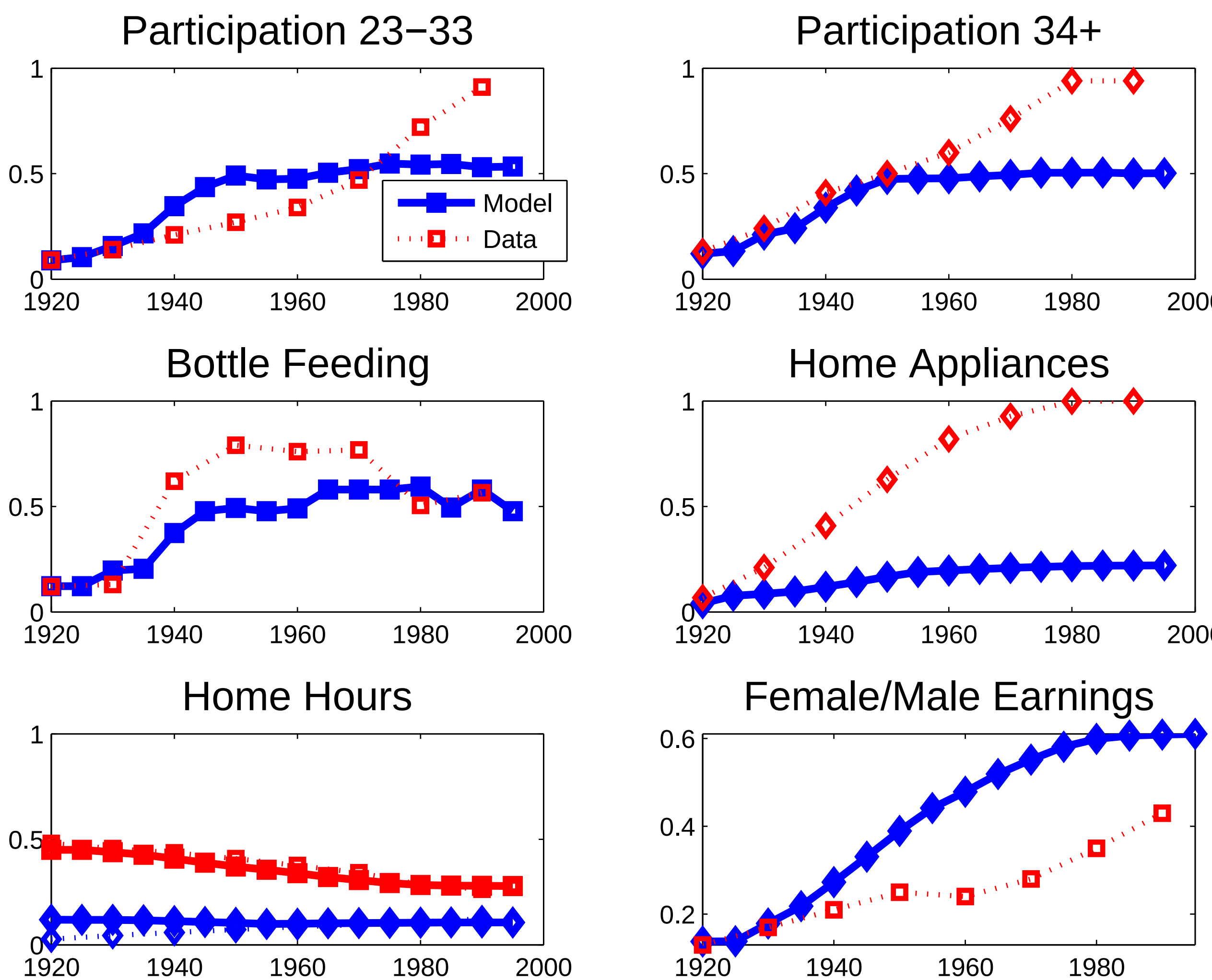

Figure 11: Predicted model transition with medical progress only.

at age 23-33 in the model is greater than the one in the data between 1940 and 1955. This period features the sharpest decline in the burden of maternal conditions, while the total fertility rate rises from 2.23 to 3.03. By 1960, participation in childbearing years predicted by the model with improvement in maternal health, at 41%, is much closer to the value observed in the data at 34%. In Section 4.4, we discuss and quantify a number of forces outside the model that may account for the slower empirical rise of participation in childbearing years over this time period. Since improvement in maternal health is only marginal after 1960, the variation in participation after this date is mainly driven by the decline in fertility.

It is interesting to compare these results to the predicted transition in a version of the model that only allows for progress in home appliances. The results are displayed in Panels B and D of Figure 12. Again, we report the simulated transition of female participation by age for the version of the model with no progress, the version with progress in home appliances only, and the full model. The decline in the time price of home appliances cannot account for the behavior of female participation at any age for cohorts in childbearing years between 1940 and 1960, who experience the high fertility rates associated with the Baby Boom. With progress in home appliances alone, participation at age 23-33 declines between 1940 and 1960. Progress in home appliances increases participation by only 7% in childbearing years relative to the version with no progress in 1960, the year in which fertility peaks in the simulation. Thus, participation for women in childbearing years in 1960 is only 14% in the model with progress in home appliances only, while it is 27% in the data. Participation at age 34+ also declines for the cohorts who experience the Baby Boom in childbearing years. For the cohort in childbearing years in 1960, participation at age 34+ predicted by the model with home appliances only is 28%, 18% higher than in the version of the model with no progress, whereas it is 60% in the data. Advances in home appliances play a greater role starting in 1965, when fertility starts to decline and the reduction in the time price of appliances is more pronounced.

The improvement in maternal health stemming from the advances in reproductive medicine also determines a rise in women's life expectancy relative to men. To isolate the marginal impact of this effect, we first simulate the model allowing only for the decline in $\tilde{M}_t$ and p_t and then we add the rising life expectancy. We find that the rise in life expectancy does not affect participation at age 23-33. It has the greatest impact on participation at age 34+ for the cohorts that are in their childbearing years in 1935-40. These women benefit of an increase in the female-male life expectancy differential, even as they experience a minimal reduction in the burden of maternal conditions in childbearing years.

4.3.3 Infant Formula

We now evaluate the marginal impact of advances in infant feeding as captured by the decline in the time price of infant formula on female participation at age 23-33. We first consider the transition in the model when progress in infant feeding is the only source of progress, that is maternal mortality and life expectancy are kept constant at 1920 levels and so is the time price of home appliances. The results are shown in Figure 13.

Progress in infant feeding has a small marginal effect on participation at age 23-33 when fertility is low and participation relatively high. Progress in infant feeding adds between 3 and 5 percentage points to participation between 1940 and 1960, when fertility is at its highest and approximately 4 percentage points from 1970 onward, when fertility is low and participation is highest. This corresponds to a 25-35% increase in participation at age 23-33 between 1945

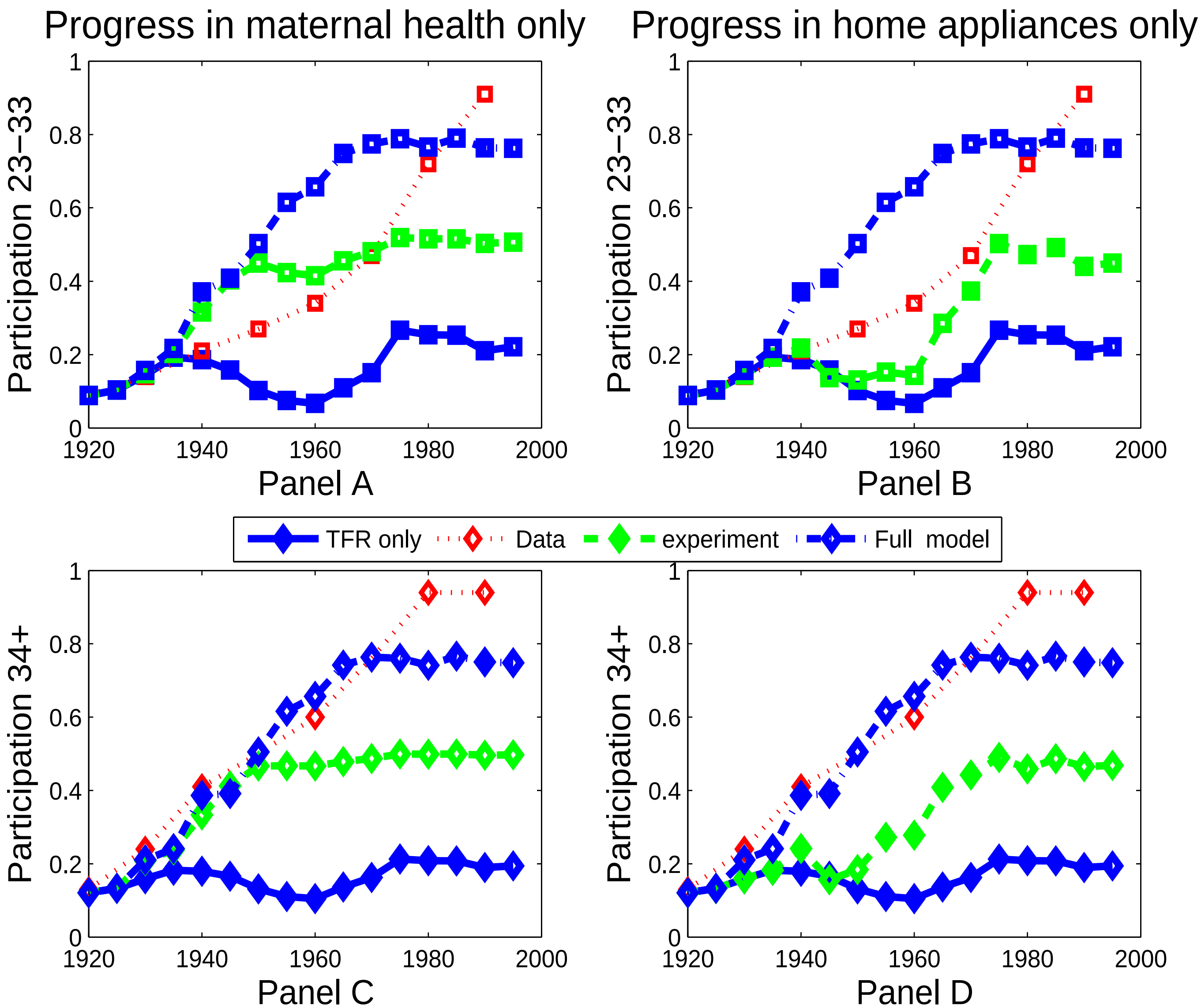

Figure 12: Isolating the effect of advances in maternal health. Comparison with progress in home appliances.

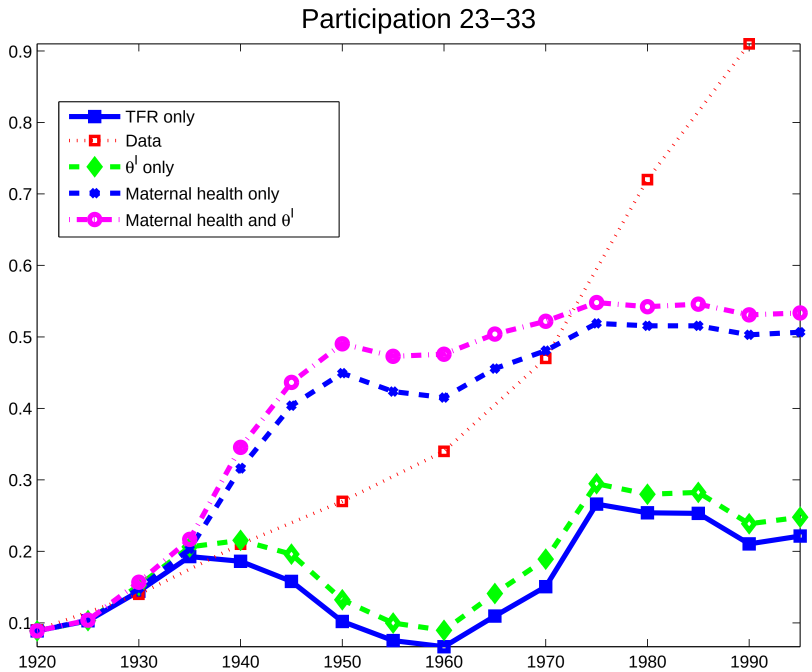

Figure 13: Effect of infant formula with and without improvements in maternal health.

and 1970. While progress in infant formula has a relatively small effect on participation when considered in isolation, it has a substantially greater impact when combined with progress in maternal health. To illustrate this, we compare the predicted behavior of female participation in childbearing years in a version of the model that only allows for progress in infant feeding, in a version with improvements in maternal health only and in the version of the model with medical progress. The results are displayed in Figure 13.

The decline in the time price of infant formula adds between 5 and 10 percentage points to participation between 1940 and 1960, the years of the Baby Boom in the simulation, and adds 4 percentage points to participation after 1960. This result suggests that the impact of infant formula on participation is greatest when the number of infants present is high and the burden of maternal conditions has dropped enough to allow for participation during childbearing years. The marginal effect of infant formula on participation is also significant after 1965, when participation is high because of low fertility as well as medical progress. Thus, only when advances in maternal health have enabled women to increase participation does the ability to avoid breast feeding have a significant additional effect on participation. The size of this effect is positively related to the number of infants present in the household.

We run a similar exercise for the version of the model with progress in home appliances and but no progress in maternal health. Progress in infant feeding has a small marginal effect (not displayed) on participation at age 23-33 when combined with progress in home appliances, adding from 3 to at most 7 percentage points to participation between 1940 and 1960. This is due to the fact that the version of the model that only allows for progress in home appliances predicts that participation in childbearing years actually declines. As noted above, the ability to avoid breast feeding has a smaller marginal effect on participation when participation is low. After 1960, progress in infant feeding adds approximately 5 percentage points to participation in childbearing years.

These results suggest that the decline in the burden of maternal conditions is the most important force driving the rise in the participation of married women during childbearing years and post-childbearing between 1935 and 1965. The decline in the time price of infant formula has a significant incremental effect on participation in childbearing years during the Baby Boom. The diffusion of home appliances cannot explain the behavior of participation for the cohorts of women that experience the Baby Boom. It exerts a more significant effect on participation post-childbearing after 1975.

4.4 Other Forces

A striking result that emerges from the previous analysis is that progress in maternal health, alone and combined with infant feeding, overpredicts participation at age 23-33 between 1935 and 1960. Moreover, even the full version of the model that includes progress in home appliances underpredicts participation at all ages after 1975. How can we interpret these findings? Clearly, the model omits additional factors that also influence married women's participation that respectively dampen and add to the effect of medical progress.

For the years between 1935 and 1965, two prime 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. Marriage bars were in place until World War II and prevailed in teaching and clerical work, which accounted for approximately 50% of single women's employment between 1920 and 1950.[41] Marriage bars disproportionately hit cohorts of women in childbearing years between 1930 and the early 1950.

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. Fernández and Fogli (2009) document the strong role of country of origin, a proxy for cultural differences in attitudes with respect to women's work, in second-generation American women's labor force participation behavior. Based on survey evidence reported in Fogli and Veldkamp (2007) and Fernández (2007), only 20% of respondents believed that a married woman should work in the period between 1935 and 1945. By 1970, this number went up to 55%, a very significant rise to a level that still suggests a significant cultural barrier to women's employment.[42]

Another possible factor is wage discrimination. Even in current years approximately 10% of the gender differences in earnings cannot be accounted for by observable differences in characteristics that are related to productivity (O'Neill, 2003). Albanesi and Olivetti (2008) 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.

[41] Goldin (1991) extensively documents the pervasiveness of these practices for different school districts and for firms hiring office workers. The probability of not retaining a single female worker upon marriage ranged between 47.5% to 58.4% for school districts between 1928 and 1942, and between 25% and 46% for firms hiring office workers between 1931 and 1940. The probability of not hiring a married woman ranged between 62% and 78% for school districts and between 39% and 61% for firms hiring office workers over the same periods.

[42] Fogli and Veldkamp (2007) and Fernández (2007) point to uncertainty about the effect of mother's work on the welfare of young children as an important determinant of these attitudes.

The fact that the model under-predicts participation relative to the data after 1975 is also not surprising since the sources of medical progress we consider are mostly exhausted by the 1960s, while several factors not present in the model may have contributed to increase married women's participation starting in the late sixties. Perhaps the most notable is the diffusion of oral contraception. The pill became available to married women during the 1960s and 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. Bailey (2006) shows that legal access to the pill before age 21 significantly reduced the likelihood of having a first birth before age 22 and increased the number of women in the paid labor force. Goldin (2006) argued that this, in turn, led to a shift from "jobs to careers" for working women. The resulting steeper path of lifetime earnings and the rise in returns to experience (Olivetti, 2006) further facilitated the rise in participation. In addition, skill biased technological change (Galor and Weil, 1996), and other labor market shifts (Blau and Kahn, 1999) also favored women.

To gauge the impact of the forces outside the model on married women's participation we run the following experiment. We set women's returns to premarital investment in market skills, ε^f, at each date so that female participation at age 23-33 in the model matches the one in the data. Given that the model over predicts participation in childbearing years between 1940 and 1960, the resulting value of ε^f will be lower than the calibrated value in those years. This is a way to quantify in the model the impact of forces, such as marriage bars, cultural aversion to women in the labor force and other forces that undermine married women's ability to participate in the labor force in those years. The effect of these forces is translated in terms of a reduction in the returns to pre-marital investment in market skills. By contrast, since the model under predicts female participation at all ages after 1975, the value of ε^f that matches the data in those years will be higher than the calibrated value. The difference can be interpreted as the positive effect of oral contraception and female biased shifts in the labor market on married women's returns to pre-marital investments.

We perform this experiment for three versions of the model: the one with only progress in maternal health, the version that also allows for advances in infant feeding, and the one that in addition includes progress in home appliances. This exercise illustrates our findings on the contribution of each source of medical and technological progress we include in the model, as well as those that are excluded. It also allows us to identify the specific time period in which the impact of each particular force is strongest.

We summarize our findings in Figure 14. It plots the value of ε^f that matches female participation at age 23-33 for the full model (dashed line) against the version of the model with medical progress only (dotted line), and for the model with medical progress and infant feeding (dash-dotted line). The constant lines correspond to the calibrated returns to pre-marital investment for females (0.61) and males (0.86). As anticipated, the value of ε^f that matches participation at age 23-33 to the data is smaller than the calibrated value for 1940-1975, and greater than the calibrated value for 1985-1990. The forces that reduced women's incentives to participate in market work between 1935 and 1970 are equivalent to a reduction of the returns to pre-marital investment in market skills of at most 15 percentage points, from 0.61 to 0.44, in 1950 in the version of the model with advances in maternal health only. The equivalent reduction is equal to at most 21 percentage points in 1950 for the version of the model which also allows for progress in infant formula, and at most 35 percentage points in the version that adds advances in home

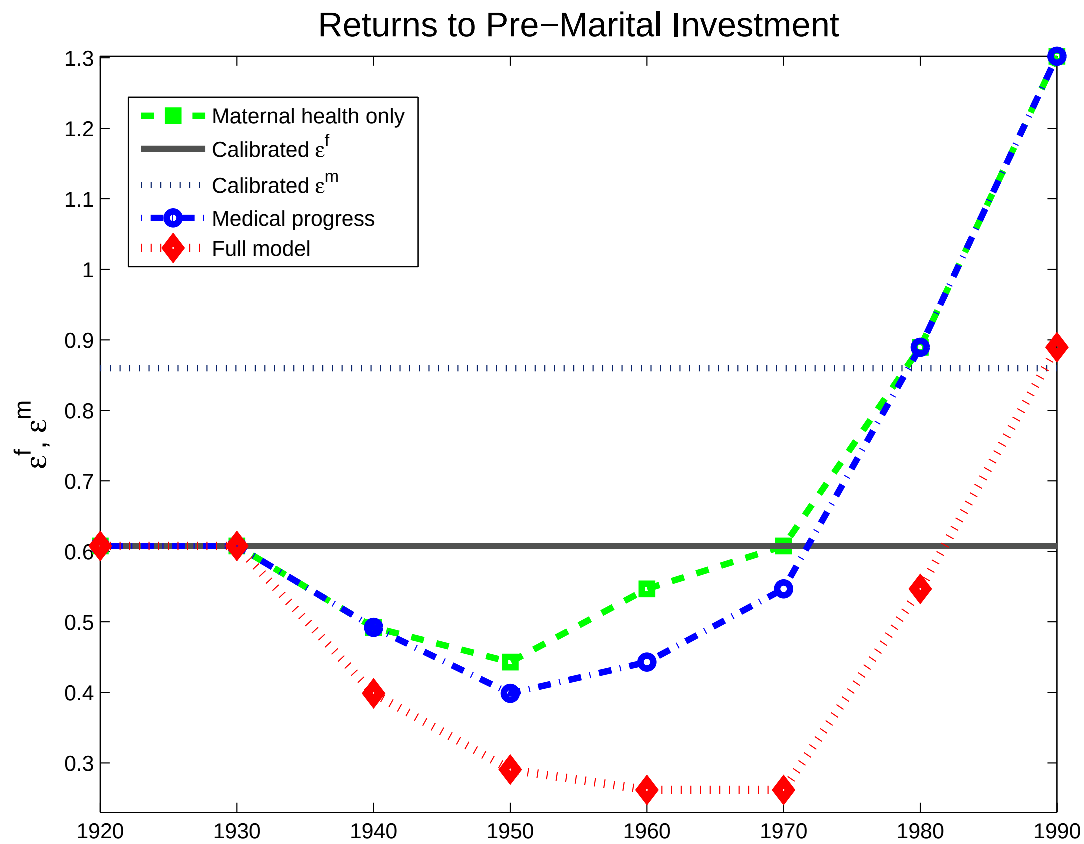

Figure 14: Effect of forces outside the model on returns to pre-marital investment in market skills.

appliances.

These results also shed further light on the contribution of advances in infant feeding to participation in childbearing years. As shown in the figure, advances in infant feeding require women's returns to pre-marital investment in market skills to be 4, 10 and 6 percentage points smaller in 1950, 1960 and 1970, respectively, than in the version of the model with improved maternal health only to match the data. The year 1960 corresponds to the peak of the Baby Boom in the model and is the year where the demand for infant formula is greatest. Thus, even if advances in infant feeding in the form of a decline in the time price of infant formula have a smaller effect on participation than improved maternal health, the ability to bottle feed is equivalent to a sizeable rise of the returns to pre-marital investment in market skills when fertility is high.[43] Similarly, progress in home appliances is equivalent to women's returns to market skills being 18-36 percentage points greater than in the model with medical progress only after 1960. Thus, even if progress in home appliances cannot account for the rise in participation during the Baby Boom, it has a significant impact when fertility starts to decline.

[43] Bottle feeding rates predicted by the model when participation at age 23-33 is matched to the data peak at the same time as in the data, though they continue to be slightly higher than in the data for 1975-1990.

5 Concluding Remarks

Our results suggest that improved maternal health contributed critically to the historic rise in married women's labor force participation during the course of the twentieth century. The diffusion of infant formula also played a significant role. Medical progress was particularly important for the cohorts of women in childbearing years between 1940 and 1965, who experienced a steep rise in fertility. By contrast, the diffusion of home appliances cannot account for the rise of participation for these women. Thus, improved maternal health is essential to explain the positive correlation between fertility and married women's participation during the Baby Boom. In addition to its implications for women's economic role, improved maternal health has broader consequences. Per capita income rises by 42% between 1920 and 1990 in the model, solely as a result of the corresponding rise in women's investment in market skills and participation. This suggests that medical progress can have powerful aggregate economic effects via its impact on maternal health.

The dynamics of fertility play a key role in women's participation in the analysis. Albanesi and Olivetti (2009) develop a model of fertility choice to explore the link between medical progress, fertility decisions and workforce behavior.

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6 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.

6.1 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 Heuser (1976). 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.)

6.2 Earnings Data

Real Wages: Real hourly wages in manufacturing (for full-time year-round workers) from Margo (2006.) Throughout the paper hourly wages and prices are deflated by using the U.S. Bureau of Labor Statistics All Urban Consumers Price Index (CPI-U) with base 1982-1984. Female/male earnings ratio: Goldin (1990, Table 3.1). This is the standard series used in the literature and it provides comparable information on the gender earnings gap for full-time year-round workers. Earnings by gender and marital status: Wage and salary income (INCWAGE) from the 1940 to 1990 IPUMS Census 1% samples (for 1970, we use the 1% State sample). Sample includes white men and women, aged 16 through 64, living in non-farm households. We further restrict the sample to observations with group quarters status equal 1, "Households under 1970 definition." For all years N/A code (999999) is treated as missing data. Statistics are obtained as weighted averages using sample-line weights (SLWT) for 1940 and 1950 and person weights (PERWT) for the remaining decades.

6.3 Female Labor Force Participation

Labor force participation (LFP) of 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 6.2) 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 23 to 35) 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 36 to 60) married women is obtained by averaging LFP statistics for the 35-64 age group across three cohorts: 1856-1865, 1866-1875 and 1876-1885. Similarly, for all the other decades. The time series data for LFP of old married women is obtained by averaging (with the appropriate population weight obtained from Haines and Sutch (2006)) LFP of married women aged 35-44, 45-54 and 55-64 by decade. LFP for never married women: Census IPUMS data (the sample inclusion rules are the same as in section 6.2) from 1900 to 2000. We count individuals whose imputed labor status is "employed" or "unemployed" (variable EMPSTAT, codes 1 and 2) as participating in the labor force (see IPUMS documentation for information on consistency of this variable across years.) For 1900 and1920 we use occupation data because information on employment status is not available. Using the 1950-standardized variable (OCC1950), we count all individuals with an "occupational response" (codes 0 through 970) as participating in the labor force. Observations with a "non-occupational response," unknown occupation or no data are, therefore, counted as non-participants.

6.4 Home Hours

We use the estimates of average weekly hours spent in home production constructed by Ramey (2009) (excel file available at http://weber.ucsd.edu/~vramey/research.html). We use the following series. Home hours by married non-working women corresponds to Ramey's estimates for housewives. Home hours by married working women and married men corresponds to Ramey's estimates for ever-married employed women and married men, respectively.

6.5 Mortality and Life Expectancy 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. Life Expectancy**:** Series Ab656-703, Haines (2006b).

6.6 YLD Calculations and Data Sources

In our calculation of the YLD we use historical data on duration and incidence of maternal morbidity and WHO disability weights for four maternal conditions: Maternal haemorrhage, 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 lenght of each model period (in months).

Maternal Sepsis: Kerr (1933) reports a 28.1 percent estimates for the incidence of infection in the production of remote disablement (Table XLI) which corresponds to a 3.4% of all live births. The outcome of maternal sepsis is either deaths or a short term disability cost for those who recover. For example, Loudon (1992, Tables 4.3 and 4.4) reports a duration of 18 to 19 days for the disablement due to maternal sepsis. Hence we set the duration of maternal morbidity for this condition to zero. This is consistent with the WHO calculation of the disability weights for this condition (see Table A2.)

Hypertensive disorders: According to historical studies reported in Loudon (1992), toxaemia 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 lenght of each model period (in months).

Obstructed Labor: Table A1 reports the information on the frequency and lenght 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 2.1.2. The incidence of morbidity due to this condition is given by 0.673 that is 1346 among the 2000 in-patients in Dr. Kerr's ward 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 lenght 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 in our calculation of YLD we do not take into account infertilty 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 hemorrhage		
Sheehan syndrom	0.065	0.065
Severe anemia	0.093	0.090
Maternal sepsis		
Infertility	0.180	0.000
Hyperthensive disorders of pregnancy		
Neurological sequelae	0.388	0.397
Obstructed Labor		
Stress Incontinence	0.025	0.025
Rectovaginal fistula	0.430	0.000

Using the above data sources and assuming a 10-year childbearing period (120 months) we obtain:

$$YLD^{14-44}_{\text{Pregnancy}} = 0.222 * 9 = 1.98 \text{ months};$$
$$YLD^{14-44}_{\text{Obstructed Labor}} = 0.081 * (0.43 * 55.67 + 0.025 * 120) = 6.56 \text{ months};$$
$$YLD^{14-44}_{\text{Sepsis}} = 0 \text{ months};$$
$$YLD^{14-44}_{\text{Hypertensive Disorders}} = 0.388 * 0.096 * 120 = 4.47 \text{ months};$$
$$YLD^{14-44}_{\text{Hemorrhage}} = 0.158 * 0.055 * 120 = 1.04 \text{ months}.$$

Consequently $YLD^{14-44} = (1.98 + 6.56 + 0 + 4.47 + 1.04) = 14.05$ months (1.17 years) for each pregnancy. Assuming a 23-year post-childbearing period, consistent with female life expectancy at age 20 in 1920 of 46.5, we obtain $Y^{44+}_{\text{Obstructed Labor}} = 0.55$, $Y^{44+}_{\text{Hemorrhage}} = 2.29$, $YLD^{44+}_{\text{Hypertensive Disorders}} = 10.30$ in months, so that $YLD^{44+} = (2.29 + 0.55 + 10.30) = 13.13$ months (1.09 years).

6.7 Breast Feeding Practices

Sources for Figure 6: The data point for 1918 is 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). It records the percentage of infants who were exclusively breast or bottle fed at 1 month or less, 3 and 6 months. The 1930 data are reported in Apple (1987, Table 9.1) and are based on a study of 200 patients at the Out Patient Department Clinic of the Massachusetts General Hospital in Boston. The study reports exclusive breastfeeding rates at 1 week or hospital discharge, 1 month or less, 3 and 6 months. The data point for 1930 should be considered a lower bound for the national average because breastfeeding was less common, both in incidence and duration, in the Northeast than in the Midwest. In order to minimize this under-estimation bias we exclude private patients since, while their breastfeeding rate at hospital discharge is as high as for clinical patients, the rate after three months is exceptionally low (as low as in the mid-1960s.)

Breastfeeding rates at hospital discharge for 1946 are from Bain's (1948) hospital survey which included more than two-third of all hospitals in the United States with at least 25 beds. The corresponding 1956 figures are from a similarly designed hospital study by Meyer (1958). This survey included about 60% of hospitals with 300 or more annual births. Both surveys report exclusive breast- and bottle-feeding rates at one week or hospital discharge (if it occurred before one week of age).

Breastfeeding rates at 6 months 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) conducted by the National Center of Health Statistics (see also Hirschman and Hendershot, 1979.) They refer to breast feeding rates for first-born babies. The entries are extracted from Figure 1 in the paper which reports the proportion of mothers breastfeeding their first infant by duration of breastfeeding and by birth cohort of mothers (in five-year intervals). We obtain the statistics by year of birth of infant by using data on mother's age at first birth from Glick (1977, Table 1). The data point in figure 6 are for the years 1935, 1941, 1947, 1951, 1955, 1959, 1965 and 1969 - corresponding to the middle point of the five-year intervals. Data on exclusive breastfeeding rate are not available in these two surveys.

In hospital breastfeeding rates for 1965 to 2001, as well as 1971 to 2001 breastfeeding rates at 6 months are from the Appendix table in Ryan, Wenjun and Acosta (2002), based on the Ross Laboratories Mothers Survey (RLMS.)

We combine these sources to obtain a continuous data series. This raises issues of compatibility between different data. Support for the comparability of RMLS and NSFG data comes from a study by Ryan et al. (1991) which shows how breastfeeding trends obtained from these two data sources are very similar.

6.8 Time and Monetary Cost of Breast Feeding

Table A3 reports information on the number of daily formula feedings 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.).

Table A3. Formula feedings per day

	min	max
<1 month	6	8
1-3 months	5	6
3-7 months	4	5
7-12 months	3	4

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 these 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 average daily intake of infant formula for an infant of median weight. 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.

6.8.1 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 of 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). We project the series forward to 2053 using the average change in the price of infant formula between 1994 and 2000.

The 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.

6.8.2 Price of Home Appliances

The time price of home appliances used in the simulations in Section 4.2 is the real value of the quality-adjusted Divisia price index for eight appliances built by Gordon (1990), rescaled by the real hourly wage in manufacturing. Since this series starts in 1947, we extrapolate it back to 1920 based on the yearly rate of change of the NIPA price index for kitchen and other household appliances (NIPA Table 2.5.4, row 30) between 1929 and 1946. The Divisia price index is available up to 1984, the NIPA price index for kitchen and other household appliances is available up to 2003. We use the post-1985 yearly rate of change of NIPA to extrapolate the Gordon series forward.