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ABSTRACT

Until the early decades of the 20th century, women spent more than 60% of their prime-age years either pregnant or nursing. Since then, the introduction of infant formula reduced women's comparative advantage in infant care, by providing an effective breast milk substitute. In addition, improved medical knowledge and obstetric practices reduced the time cost associated with women's reproductive role. We explore the hypothesis that these developments enabled married women to increase their participation in the labor force, thus providing the incentive to invest in market skills, which in turn reduced their earnings differential with respect to men. We document these changes and develop a quantitative model that aims to capture their impact. Our results suggest that progress in medical technologies related to motherhood was essential to generate a significant rise in the participation of married women between 1920 and 1950, in particular those with young children.

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Gender Roles and Technological Progress*

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May 31, 2007

Abstract

Until the early decades of the 20th century, women spent more than 60% of their prime-age years either pregnant or nursing. Since then, the introduction of infant formula reduced women's comparative advantage in infant care, by providing an effective breast milk substitute. In addition, improved medical knowledge and obstetric practices reduced the time cost associated with women's reproductive role. Our hypothesis is that these developments enabled married women to increase their participation in the labor force, thus providing the incentive to invest in market skills, which in turn reduced their earnings differential with respect to men. We document these changes and develop a quantitative model that aims to capture their impact. Our results suggest that progress in medical technologies related to motherhood was essential to generate a significant rise in the participation of married women between 1920 and 1950, in particular those with young children.

1 Introduction

The twentieth century saw a dramatic rise in the labor force participation of married women, particularly those with young children, leading to a revolutionary change in women's economic role. We examine the contribution of progress in medical technologies related to motherhood to this process and argue that it played a critical role.

Women's reproductive duties occupied a significant portion of their married life up until the early 20th century. Our estimates indicate that in 1920 women spent over 60% of their prime-age years either pregnant or nursing. High infant mortality added to the amount of time women devoted to their maternal role, since the frequency of pregnancies was much greater than the frequency of live births for the average woman. Even as women increasingly gave birth in hospitals, poor obstetric practices implied that delivery was a very risky procedure, leading to often extended, sometimes permanent, periods of effective disability for the mother and frequently to death of the mother and/or the child. Moreover, most women breast fed their infants for an extended amount of time. These biological demands on women reduced their ability to participate in the labor force and substantially weakened their incentives to invest in labor market skills.

*For useful comments, we wish to thank Raquel Fernandez, Claudia Goldin, Jeremy Greenwood, John Knowles, Roberto Samaniego, and participants at the LAEF conference on "Gender, Households and Fertility" at UCSB, the New York/Philadelphia Workshop on Macroeconomics, the SED 2006 Annual Meeting, and the North American Econometric Society Meetings. This material is based upon work supported by the National Science Foundation under Grant No. 0551511. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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Our hypothesis is that progress in medical technologies related to motherhood was critical to the rise in married women's labor force participation. The resulting reduction in the physiological constraints related to motherhood enabled married women with children to enter the labor force and provided an incentive to invest in market skills, thus reducing gender earnings differentials. We start by providing evidence on two dimensions of medical progress that reduced the time spent by women in reproductive duties. The first is the development and commercialization of a 'humanized' infant formula, which reduced women's comparative advantage in infant feeding by providing an effective breast milk substitute. The second dimension corresponds to progress in scientific and medical knowledge leading to improved obstetric practices, new treatments and medication that generated a decline in maternal mortality and the incidence of post-partum disabilities, as well as infant mortality, thereby reducing the number of pregnancies for given completed fertility. We then develop a model that aims to capture these forces and use it to quantitatively evaluate their impact on the evolution of married women's labor force participation, home hours and gender earnings differentials during the course of the twentieth century.

The model features overlapping generations of agents that live for three periods. In the first period, agents are single and they can make an investment in market skills, which increases their wages in future periods. They are married in the second and third period of their life. Their utility is defined over consumption, leisure in all periods and two different home goods. The *general household good* is valued at all ages and corresponds to activities such as meal preparation, child care, cleaning, yard work and other household chores. Both husbands and wives can contribute to the production of general household goods. The *infant good* represents those activities strictly connected to the existence of infants in the household, namely pregnancy, childbirth and feeding. This home good is only valued in the second period of life, which we take to correspond to the fecund years, and *only* wives can contribute to its production. There are two technologies, old and new, for the production of each home good. For general household goods, both technologies require the spouses' time and home durables, but the new technology is more durables-intensive than the old. For infant goods, the old technology just requires mothers' time, while the new technology also uses market goods. The old technology for producing infant goods corresponds to breast-feeding, while the new technology corresponds to the use of infant formula. If the new infant good technology, infant feeding becomes a general household good. This has the effect of degendering home production in those households that adopt the new technology, though the wife is still subject to a time cost of pregnancy and childbirth in the first period of married life. For both home goods, households must pay to adopt the new technology, while the old technology is free. This cost reflects the value of the additional market goods required by the new technology. Households make Pareto efficient decisions on the choice of home production technology, labor force participation and the allocation of home hours across spouses. The division of labor within the household and gender differences in wages are both endogenous.

We allow for four exogenous sources of technological change. The first is the increase in average labor productivity, due to technological progress in market production. The second is the improvement in general household technologies, as reflected in the decline in the time price of the new general household good technology. Third, the introduction of time savings infant feeding technologies and their improvement over time, as reflected in the decline in the time price of breast-milk substitutes. Lastly, the reduction in the time cost of pregnancy driven by improved medical practices and knowledge, as well as by changes in fertility. The first and second factors influence the opportunity cost of home production for *both* genders. The third and fourth factor have a direct impact on women only.

To evaluate the role of these factors on the dynamics of married women's labor force participation, as well as on other important variables, such as the female/male earnings ratio, home hours and women's investment in market skills, we construct measures of these variables for the time period between 1920 and 1970 and feed them into the model to examine the properties of the transition. The improvements in households technologies are proxied by the decline in the time price of home durables and infant formula over the period 1920-1970. For the general household technology the time price series is based on Gordon's (1990) Divisia price index for home durables. For the new infant good technologies, the time price series is based on a price series for Similac, the first commercial 'humanized' infant formula in the U.S., that we construct from advertisements in historical newspapers for three major U.S. metropolitan areas.

We calibrate our model to match technology adoption rates, male and female home hours conditional on participation and cohort-specific labor force participation rates of married women in 1920. We then simulate the transition in our model and run several experiments to evaluate the impact of each force in isolation. We find that there is a strong complementarity in the adoption of new infant feeding practices and labor force participation of married women. If women must breast-feed, this discourages female participation in market work when infants are present and women's investment in market skills. Women's lower earnings potential relative to men increases their home hours and reduces women's labor force participation even in the old period, when they are completely symmetric relative to men. Hence, improvements in medical technologies that reduce mothers' required time for infant care are a necessary pre-condition for the adoption of new home durables technologies and the rise in labor force participation of married women.

Improvements in medical and home technologies are a powerful force in our framework. The model overpredicts the rate of adoption of the new infant feeding technologies and the labor force participation rate of married women with children relative to the data. This result is not surprising given that technological progress is the only force at work in our model, while other offsetting factors were present in practice. The pervasive presence of "marriage bars" in teaching and clerical work, which comprised a very large fraction of female employment, undoubtedly contributed to depress the participation rate of married women (Goldin, 1990). Cultural factors, as emphasized in Fernandez and Fogli (2005), or statistical discrimination driving gender wage differentials as in Albanesi and Olivetti (2006), may also have reduced the effect of technological progress in home production. Our experiments suggest that improvements in infant good technologies account for a large fraction of the increase in the labor force participation of married women with children between 1920 and 1950, while improvements in general household technologies play the most important role between 1950 and 1970. On the other hand, the increase in overall labor productivity alone does not lead to a rise in female labor force participation, because by itself it does not alter the optimal division of labor within the household.

Our paper is related to the literature on the effects of technology on the household and women's labor market outcomes. Greenwood, Seshadri, Yorugoklu (2005) argue that the introduction of home appliances was a critical determinant of rising female labor force participation in the course of the twentieth century and explains about half of the rise in female labor force participation between 1900-1980. The remaining fraction is accounted for by an exogenous decline in the gender gap in wages. However, the labor saving features of new home appliances in principle benefits both genders. In their model, the rise in female labor force participation resulting from the mechanization of home work stems from the assumption that only women can engage in home production. The contribution of our paper is to isolate forces of technological progress that are intrinsically gendered and *directly* affect women and evaluate their effect in a setting where *both* the division of labor in the household and gender wage differentials are endogenous. Moreover, the improvement in obstetric practices and medical knowledge, as well as the introduction of infant formula, preceded the take-off in participation of married women and were largely driven by public-health considerations. On the other hand, the commercialization of modern home appliances largely occurred after World War II and may well have been driven, at least in part, by rising demand from women participating in the labor force.

Greenwood and Guner (2005) relate the improvements in household technologies to the decline in marriage rate and the increase in the incidence of divorce. Goldin and Katz (2002) show that the availability of oral contraceptives starting in the late 1960's contributed to the increase in the number of college graduated women into professional programs and to the decline 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.

The paper is organized as follows. Section 2 provides a detailed history of the developments in infant feeding technologies and practices in the 20th century and describes our data on the price of infant formula. In addition, it provides information on other medical developments related to motherhood. Section 3 describes our analytical framework. Section 4 discusses our calibration strategy and presents the results of our experiments. Section 5 concludes.

2 Progress in medical technologies related to motherhood

Women's maternal role was associated with a considerable time commitment.[1] Consider the median woman in 1920. She married at age 21 and had on average 3.26[2] children over her lifetime, with her first birth at age 23 and her last at age 33. However, given the high infant mortality rate, she experienced more than three pregnancies. Based on our estimates of infant survival probabilities, an average woman experienced 3.6 live births for a completed fertility of 3.26 children. Given that a pregnancy lasts approximately nine months, an average woman would spend 3.26 years between age 23 and age 33 pregnant, that is 32.6% of her time endowment.[3] Moreover, women suffered significantly during pregnancy, childbirth and after delivery. Childbirth itself was perceived as a very risky event, a perception that was justified. Levitt (1986) documents that for many women the process of giving birth would lead to permanent physical disabilities and, in the extreme, death. In 1920, one mother died for each 125 living births. Given that women delivered 4.35 live infants over the course of their fertile years, then a woman's compounded risk of dying of childbirth was 3.5% or 1 in 29. A very considerable number.

An additional factor to consider in that most infants were breast fed by their mothers until the early decades of the 20th century. Nursing is a very time intensive activity. Based on a completed fertility rate of 3.26 children, each breast fed for 12 months, the average woman would be nursing for 32.6% of the years between age 23 and age 33 in 1920. The estimated average time required to breast-feed one child for the first 12 months ranges between 14 and 17.30 hours per week based on the National Association of Pediatrics infant feeding charts.[4] This means that on average women would spend 35% to 43% of their working time nursing, given an average workweek of 40 hours.

[1] The data sources for all the statistics mentioned in this section are in the Data Appendix.

[2] This number corresponds to the total fertility rate (TFR) for 1920. The TFR represents the best estimate of a woman's completed lifetime fertility available in the data. See Greenwood, Seshadri, Vanderbroucke (2005).

[3] The calculations underlying this discussion are presented in Section 2.4.

[4] See appendix for details.

We summarize these calculations in the following table. The total time cost associated with maternity amounts to 65.2% of a woman's time endowment during her prime age years in the early 1920s. This is a very sizeable fixed cost.

Table 1: Time Cost of Maternity in 1920		
DETERMINANTS		
TFR	Mortality Rates	Live Births per Woman
3.26	Infant 8.6% Maternal 0.8%	$\frac{3.26}{1-0.086} = 3.6$
TIME COST ESTIMATE		
PREGNANCY		NURSING
$4.35 \times \frac{9}{12} = 3.26$ years		$\frac{12}{12} \times 3.26 = 3.26$ years

The rest of this section documents two aspects of progress in medical technologies that contributed to reduce the time commitment associated to women's maternal role: the introduction and development of 'humanized' infant formulas and the resulting change in breast feeding practices, as well as the medical advancements that reduced infant and maternal mortality rates and the time cost of pregnancy, childbirth and subsequent recovery.

2.1 A short history of infant formula

Until the early decades of the 20th century, cows' milk and hiring a wet nurse were the only two alternatives to mother's milk. In the last decades of the 19th century, both these alternatives were proven inadequate. On the one hand, the new discoveries in bacteriology pointed to a connection between high infant mortality and tainted milk supplies, leading to a variety of public health initiatives. (See Table 2.) On the other hand, the development of physiology and nutritional science uncovered a link between the high occurrence of infant deaths and poor nutrition (Mokyr, 2000). These new scientific discoveries spurred a quest to develop effective substitutes for mother's milk in the second half of the 19th century.[5]

The first chemical analysis of human and cow's milk, published in 1838, showed that cow's milk was a very poor alternative to mother's milk since it contained a much higher level of proteins (especially caseins) and a lower amount of fat and carbohydrates (especially lactose). As a result of this research the first baby food products, such as Leibig's, Nestle's and Mellin's infant food, were developed and introduced commercially between the 1870s and the 1890s. These products were essentially cow's milk modifiers. That is, the powdered formulas contained a combination of malt, wheat flour and sugar intended to modify cow's milk to make its content more similar to that of human milk. The powder was mixed with hot cow's milk and diluted with water to obtain a 'ready-to-feed' infant formula that, although better than cow's milk, was still very different from maternal milk in terms of its nutritional content.[6]

Pediatricians strongly opposed these products and discouraged mothers from buying them. Infant feeding studies became the most important sub-field in pediatrics as doctors worked to develop more scientific methodologies for modifying cow's milk. The most successful method was

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

[6] Table A1 in the appendix reports data on the composition of the different types of milk and baby formulas discussed in this section.

Rotch's "percentage method" that became the medical gold standard for infant feeding between 1890 and 1915. Rotch's method was so complex that the formula was mostly produced in milk laboratories and distributed through pediatricians.[7] Moreover, the resulting infant formula was still nutritionally inadequate relative to mother's milk, and as first shown in a 1902 Boston Medical and Surgical Journal Article, commonly inaccurate..

The big scientific breakthrough in infant feeding occurred in the early 1920s when nutrition scientists succeeded to create 'humanized' infant formulas that exactly matched the composition of maternal milk in terms of its fat/proteins/carbohydrates content. The first two formulas studied to resemble mother's milk, SMA (for "simulated milk adapter") and Similac (for "similar to lactation"), were created in 1919/1920 and are still sold in stores today. These humanized infant formulas were approved by the medical profession[8] and pediatricians encouraged mothers to use them if they encountered problems breast-feeding or if they deemed the mother's milk nutritionally inadequate for the baby. We focus on Similac, in this paper, because it was the first humanized infant formula to be introduced on the mass-market, in 1926, and to become popular. In 1975, 52% of infants receiving commercially prepared milk-based formulas were fed Similac (see Table III in Fomon, 1975) and this formula remains very popular to this day.[9]

2.2 Changes in breast-feeding practices: 1920 to 1970

The introduction of effective and easy-to-prepare infant formulas, as well as improvements in bottle feeding technology, such as the collapsible, sanitary, and disposable plastic bottle,[10] induced a dramatic shift from breast- to bottle-feeding between the 1920s and the early 1970s. To document this phenomenon, we mainly rely on two studies, Hirschman and Hendershot (1979) and Hirschman and Butler (1981), that combine data from the 1965 National Fertility Study and from the 1973 National Survey of Family Growth (Cycle I) conducted by the National Center of Health Statistics. These sources report information on changes in breast-feeding practices both by mother's birth cohort and by child's year of birth.

Figure 1 reproduces Figure 1 in Hirschman and Butler (1981). Each line represents successive cohorts of U.S. mothers, from those born in 1911-1915 to those born in 1945-1950.[11] For each cohort, the figure reports the proportion of mothers that breast-fed their first born at birth (the intersection of each curve with the vertical axis) and who continue to breast-feed over the first 13 months of the infant's life. More than two thirds of mothers who were born during the first half of the 1910s breast fed their first child at birth, and more than 40% of women belonging to this cohort were still breast feeding at 6 months. Since the median age at first birth in 1920 was approximately 23, this cohort of women approximately had their first child in 1933-1937. For the cohort of women who were born in the second half of the 1940s, only about 25% breast fed

[7] The formula could also be made at home through a complicated and time and labor intensive process. Newspapers from the time include a very large number of classified ads for nurses specialized in making formula according to Rotch's percentage method.

[8] The name Similac was proposed by Morris Fishbein, the editor of the Journal of the American Medical Association in the 1920s (Schuman, 2003). Additional details on the history of Similac are in the appendix.

[9] 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). Alternative scientific infant formulas, such as Enfamil, were launched on the market much later, in 1959.

[10] Ruth Cowan (1979) argues that the baby bottle "revolutionized a basic biological process, transformed a fundamental human experience for vast numbers of infants and mothers".

[11] For the 1911-1915 to 1931-1935 cohorts data are from the 1965 National Fertility Study. For the remaining cohorts data are from the 1973 National Survey of Family Growth, Cycle I.

their first child and less than 5 percent continued for 6 months. Given that the median age at first birth was approximately 21 for this cohort, these women had their first child in 1966-1971. The decline in breast-feeding rates is very dramatic and sudden, occurring over the span of two generations, and was particularly strong at longer breast-feeding durations. A similar pattern emerges for breast-feeding rates by children's birth cohort (see Table A2 in the Appendix). The study by Hirschman and Butler also presents evidence on how breast feeding rates vary with mothers' characteristics such as education, income and labor force participation over this period. Interestingly, from 1950 to 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.

Additional evidence on breast- and bottle-feeding rates before 1930 is provided in Apple (1987, Table 9.1). The data come from a series of studies conducted by the Children Bureau for different geographical areas during the period 1917-1919. These studies show that, averaging across locations, 88% of newborn were exclusively breast-fed at 1 month and approximately 50% of the babies were still breast fed at 6 months of age in the late 1910s. These statistics, although not directly comparable, are consistent with the evidence for the 1930s discussed above.

The evidence on trends in the use of commercially prepared formulas is not as systematic as the one reported above and is only available since the 1950s. It is mainly based on the Ross Mother's Survey that was conducted by Ross Laboratories in Ohio, the current producer of Similac, from 1955 to the late 1980s.[12] Based on this survey, 30% of 2 to 3 month-old infants were fed using commercially prepared formulas in 1955. This fraction increased to 70% in 1970 (Fomon, 2001). Moreover, although only 23.2% of infants received commercially prepared formula at 1 week of age in 1955 approximately 75% of them did in 1970.

According to all records, the 1970s marked the lowest incidence of breast-feeding of the entire 20th century. Breast feeding rates have increased steadily since the late 1970s, owing to new medical findings on the immunization properties of human milk and to a growing effort to promote breast feeding in the scientific and popular press. In year 2003 approximately 71% of mothers breast fed at birth and 62.5% exclusively breast fed their baby at 1 week. These rates are comparable to those observed in the 1930s.[13]

2.3 Price of Similac

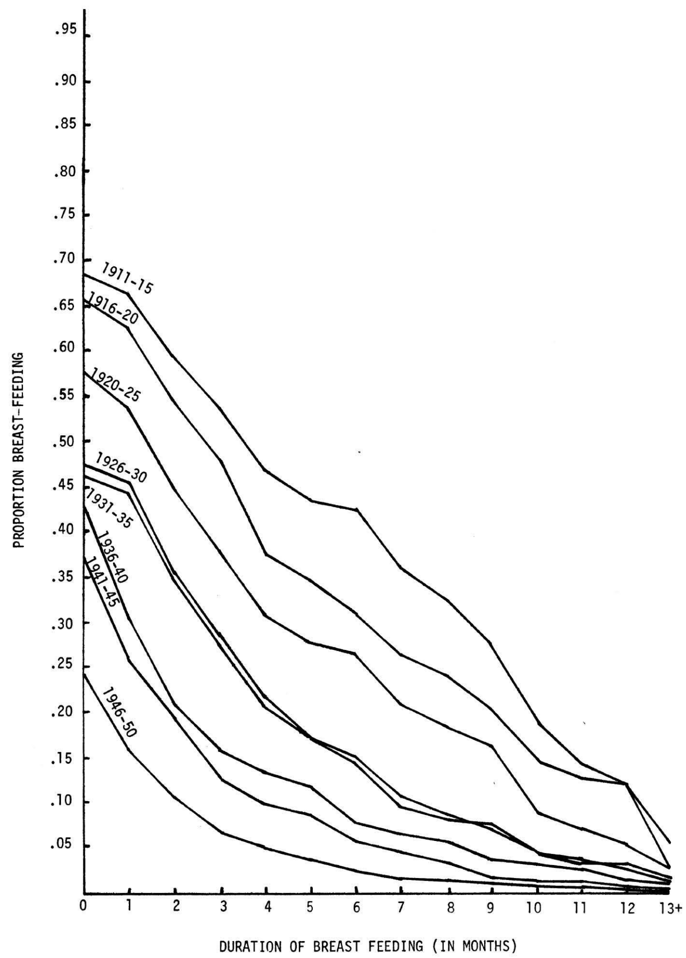
We posit that improvements in infant feeding technologies are embodied in infant formula. To measure the advancement in this technology, we construct a time series for the price of Similac based on advertisements from the Chicago Tribune, the Los Angeles Times and the Washington Post from the mid-1930s to 1985.[14] We then derive a series for the *time price* of Similac, using a measure of hourly wages to deflate the original price series after adjusting for nominal inflation. The resulting time price series is our proxy for the advancement in infant feeding technologies over the period of interest.

[12] Survey data were obtained through questionnaires mailed to a sample of the national distribution of infants up to 6 months of age. See Martinez and Nalezienski (1979) for a discussion of the survey design and of the potential biases associated with it.

[13] Breast feeding rates are up at all durations. In year 2003 36.2% of mothers still breast feed at 6 months but only 14.2% of mothers exclusively breast feed. At 12 months 17.2% of mothers breast feed (National Immunization Survey, CDC, 2003).

[14] 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.

feed by cohort2



1.jpg

Figure 1: Proportion of mothers breast-feeding their infants by duration of breast-feeding (in months) and by birth cohorts of mothers.

The historical ads provide information on price, quantity and type (powder, concentrated liquid, ready-to-feed) of Similac in drugstore chains such as Walgreens and Stineway. The price observations refer to items on sale, hence, we interpret them as a lower bound for the price of Similac. For each year in the sample and for each city we have monthly observations that we use to construct our yearly series. We present data computed by averaging prices of powder and concentrated liquid Similac across the three cities.

The first data point available is for 1935. During that year, a 16 ounces can of powder Similac was sold for $6.40 (in 1982-84 dollars). By 1959 the same can of Similac sold for $3.38 - this corresponds to a 40% decline in the price of Similac. In the mid 1950s, a liquid version of Similac was also commercialized. A 13 liquid ounces can sold for approximately $1.00. In 1965, the unit price of the same item was 70 cents, which represents a 30% reduction in the unit price. By 1975 the price dropped an additional 20% to $1.40 for a 32 ounces can of liquid Similac.[15]

We convert the data into a time price series by dividing the real price of one 'ready to feed' liquid ounce of Similac by the real hourly wage in manufacturing.[16] The time price of Similac, in percentage terms, is plotted in red in Figure 2. The interpretation of the numbers in the figure is as follows. A time price of 2 would imply that in order to buy 1 liquid ounce of 'ready to feed' Similac a worker in manufacturing would need to work 2% of an hour that is, 1.2 minutes. This series drops by an average of 5.1% per year between 1935 and 1970. We use this estimate in our transitional simulations. We also report the time price series for the first generation milk modifier formulas starting in 1892 by using the same data collection strategy used for Similac for Mellin's and Nestle's. The corresponding time price of one 'ready to feed' liquid ounce of formula are reported in blue in Figure 2. Although we do not use the entire series in our calibration exercise, the figure exemplifies the large drop in the time price of infant formula that occurred before our period of interest. The reported time prices for the two types of formula are not quality adjusted. Quality adjustment would intensify the decline in the time price of formula since, as discussed above, Similac was a better product in terms of its nutritional contents than Mellin's and Nestle's.

How expensive it was to feed an infant with Similac in 1935? The total cost of exclusively bottle-feeding an infant, taking into account that the amount of formula needed varies by the infant's weight and the number of feedings per day varies by age (see Data Appendix for details). In 1935, the cost *per day* of exclusively bottle-feeding Similac to a baby boy of median weight during the first month of life amounted to $1.25 to $1.67 in 1982-1984 dollars. Then, the annual total cost of bottle feeding a baby boy of median weight during his first year of life ranged between $615 and $790 in 1935 (in 1982-1984 dollars). This cost is very significant since the personal disposable income per capita in 1935 was $1624 (in 1982-1984 dollars). By year 1970 the cost of exclusively bottle feeding a baby boy of median weight during his first year of life ranged between $171 and $219 (in 1982-1984 dollars).

2.4 Trends in infant mortality

Two other important trends emerged in the 20th century: the decline in infant and maternal mortality. These trends are driven by independent progress in scientific and medical knowledge

[15] Thoughout the paper dollar prices are adjusted using the U.S. Bureau of Labor Statistics All Urban Consumers Consumer Price Index (CPI-U) with base 1982-1984. The index is an average of prices for all items in the CPI and across all U.S. cities. Monthly data are deflated by using the monthly CPI index.

[16] Throughout the paper our measures of hourly wages is series Ba4361 from the Statistical Abstracts of the United States: Bicentennial Edition (2006). Hourly wages (for full-time year-round workers) are also expressed in 1982-1984 U.S. dollars.

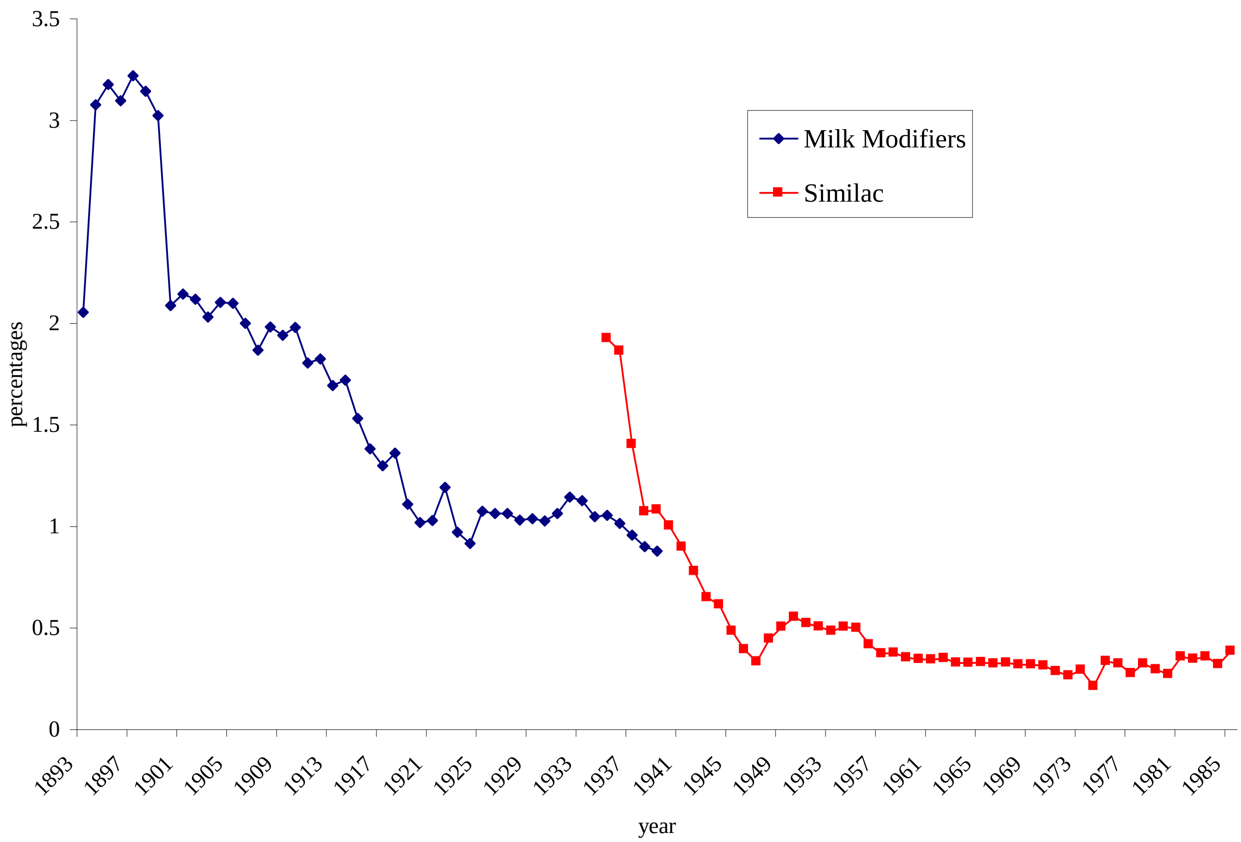


Figure 2: Time price of Infant Formula

that started in the early years of the 19th century, as well as a rising concern for public health emerging in the same period, leading to various initiatives to improve sanitation in urban areas.

Public health initiatives were initially targeted to two main concerns: water treatment and sewage facilities, and the quality of milk supplies. Diarrhea and dehydration were a major factor in infant mortality beyond the first week of life and were first linked to contaminated water or milk supplies in the 1850s. Table 2 lists the main developments in the area of public health.

The major urban areas were at the forefront in the effort to improve sanitation conditions and ensuring the purity of food supplies and initiatives were mostly local in nature. In 1875, none of the U.S. cities with a population of 100,000 or more used any kind of formal treatment for its sewage waters. Progress was slow and uneven in this area. Only Worchester, MA, and Reading, PA, had installed formally designed treatment facilities in 1900. In 1926, only twenty major cities had sewage treatment plants. By the 1940s, most major metropolitan areas had developed water treatment and sewage disposal systems. Chicago was the first city to institute a licensing system for milk dealers in 1877. In New York, the first pasteurized milk station was opened in 1893. But it wasn't until 1906 that the first federal piece of legislation on the purity of food supplies was passed. The link between children's health and environmental conditions in urban area was firmly established in the public debate. This led President Taft to create the US Children's Bureau in 1912, a federal agency, with the purpose of investigating high infant mortality and other social issues and providing workable solutions.

Table 2: Timeline in Public Health Initiatives

1850	Massachusetts review of sanitation practices leads to creation of local health office to enforce sanitary code. Other localities follow.
1854	Dr. Snow demonstrates how cholera spread via water supplies in London.
1892	Chicago health commission attributes high infant mortality to unsanitary milk supplies. Bureau of Milk Inspection established in 1893. Milk certification extended to Illinois in 1895.
1892	Bruster, NY, first city to treat sewage waters with chlorine. By 1940, treatment covers 70% of the population of major American cities.
1900	Chicago completes first component of The Sanitary and Ship Canal project, reversing flow of Chicago River away from Lake Michigan.
1906	First Federal Pure Food and Drug Act passed by congress.
1908	Josephine Baker appointed head of first Bureau of Child Hygene in New York City.
1912	US Children's Bureau established. First "Children's Year" sponsored in 1818.
1921	Sheppard-Towner Maternity and Infancy Protection act enacted by Congress.

The public health initiatives played a substantial role in the initial decline of infant mortality rates over the first three decades of the 20th century (see Figure 3). In 1915, approximately 100 infants per 1,000 live births died; by 1930, this rate dropped to 64.6 infants per 1,000 live births - a 35% decline.

The additional factors behind high infant mortality until the mid 1930s included still births and high rates of perinatal deaths. Many stillbirths were the outcome of fetal asphyxia in the frequent cases of difficult labor. The high rates of perinatal death stemmed from infants' very poor conditions at birth, often due to bad health and nutrition of the mothers and lack of prenatal monitoring (see O'Dowd and Phillipp, 1994). Additional causes of infant death beyond the first week were congenital malformation, infection, often contracted from the mother during labor.

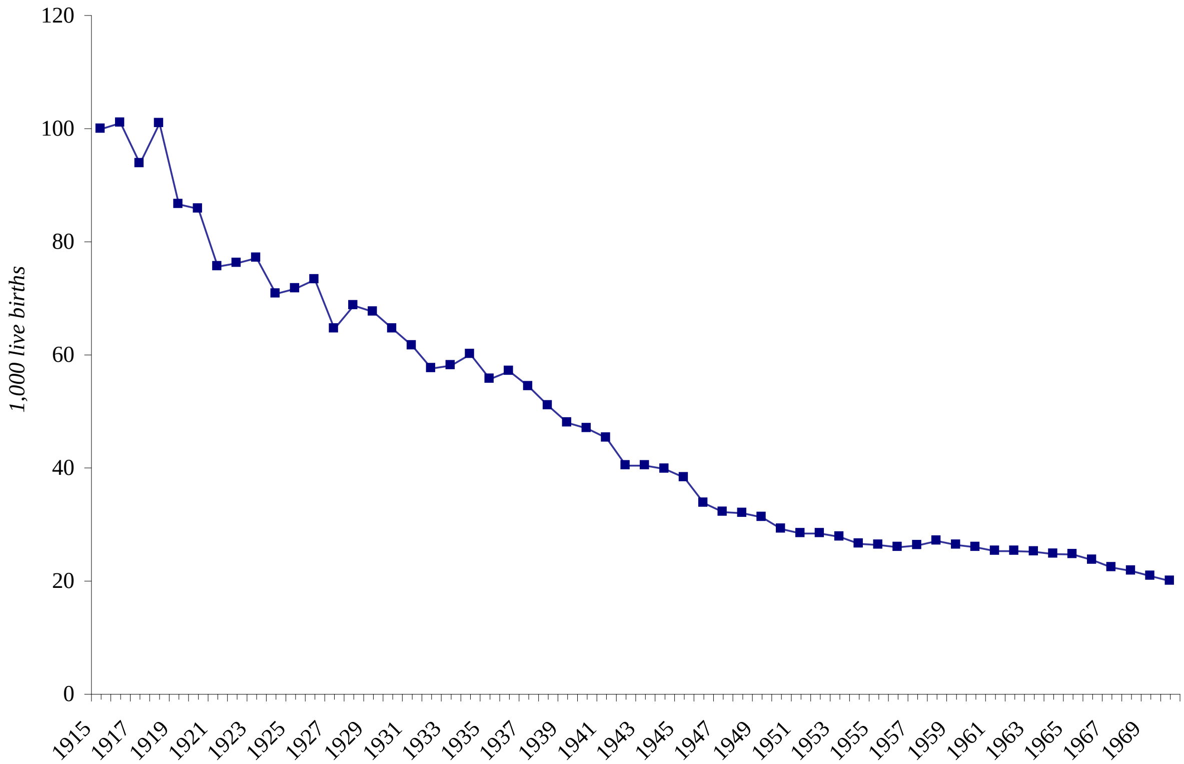


Figure 3: Infant deaths per 1,000 live births.

The largest observed decline in infant mortality -over 60%- occurs between 1935 and 1955, and is mostly driven by medical progress. Improved obstetric practices, see Table 4, reducing the incidence of difficult labor greatly contributed to the reduction in perinatal deaths. Systematic efforts to provide comprehensive maternal and infant care with prenatal and post-partum monitoring and home visits by health workers began the mid 1920s. The medical advances that occurred in the 1930s and 1940s, including the introduction of antibiotics, blood banking and safe blood transfusion, as well as the development of fluid and electrolyte replacement therapy, were undoubtedly the most important contributors to this trend until 1950.[17] By 1955, the infant mortality rate had declined to 26.6 infant deaths per 1,000 live births. The decline was more gradual after that. In 1975, there were 16.1 infant deaths per 1000 live births.[18] Table 3 lists the main developments in the area of fetal and neonatal health that contributed to the reduction in infant mortality rates.

Table 3: Timeline for Infant Health

1816	John Davidson investigates the causes of mortality in children.
1822	Stethoscope introduced for fetal auscultation during pregnancy and labor.
1828	Charles Billard wrote a clinico-pathological text on the newborn.
1848	Vacuum extractor demonstrated. Led to modern vacuum extractor in 1953.
1858	Benefits of phototherapy discovered.
1860	Axis-tracation forceps developed.
1872	Alexander Gueniot defined prematurity by weight.
1880	Introduction of incubators for neonatal care.
1889	Inaugural meeting of the American Pediatric Society.
1890	Fluid replacement therapy introduced. Replaced by blood transfusions in 1920.
1906	Fetal electrocardiograph first performed. Becomes more widely used in 1930s.
1909	Ventilation therapy pioneered.
1925	First successful exchange transfusion carried out.
1930	American Board of Pediatrics established.
1935	Vitamin K therapy introduced to prevent hemorrhagic disease of the newborn.
1940s	Oral electrolyte replacement therapy introduced.
1953	Virginia Apgar pioneered the newborn evaluation score

The decline in infant mortality had a direct impact on the time spent by women in reproductive duties since it reduced the occurrence of pregnancies and breast-feeding for given completed fertility. The following calculations explain the link between the infant survival probability and the time cost of pregnancy for a given value of the total fertility rate. The probability of survival to 12 months for the average newborn can be calculated by using information on the infant mortality rate and on the number of live births in a given year. For example, in 1920, 85.8 infants died for each thousand live births. Then, the probability of a child surviving his first year of life in 1920 was 91%. By repeating this calculation for each year between 1920 and 1970 we obtain a time series for the the infant's survival probability.

This series as well as the total fertility rate (TFR) and the resulting number of life-time live births per woman are plotted in Figure 4. A decline in infant mortality rate determines a decline

[17] See Guyer, Freedman, Strobino and Sondik (2000).

[18] Source: U.S. Census Bureau, Statistical Abstracts of the United States. Mini-Historical Statistics, Table HS-13.

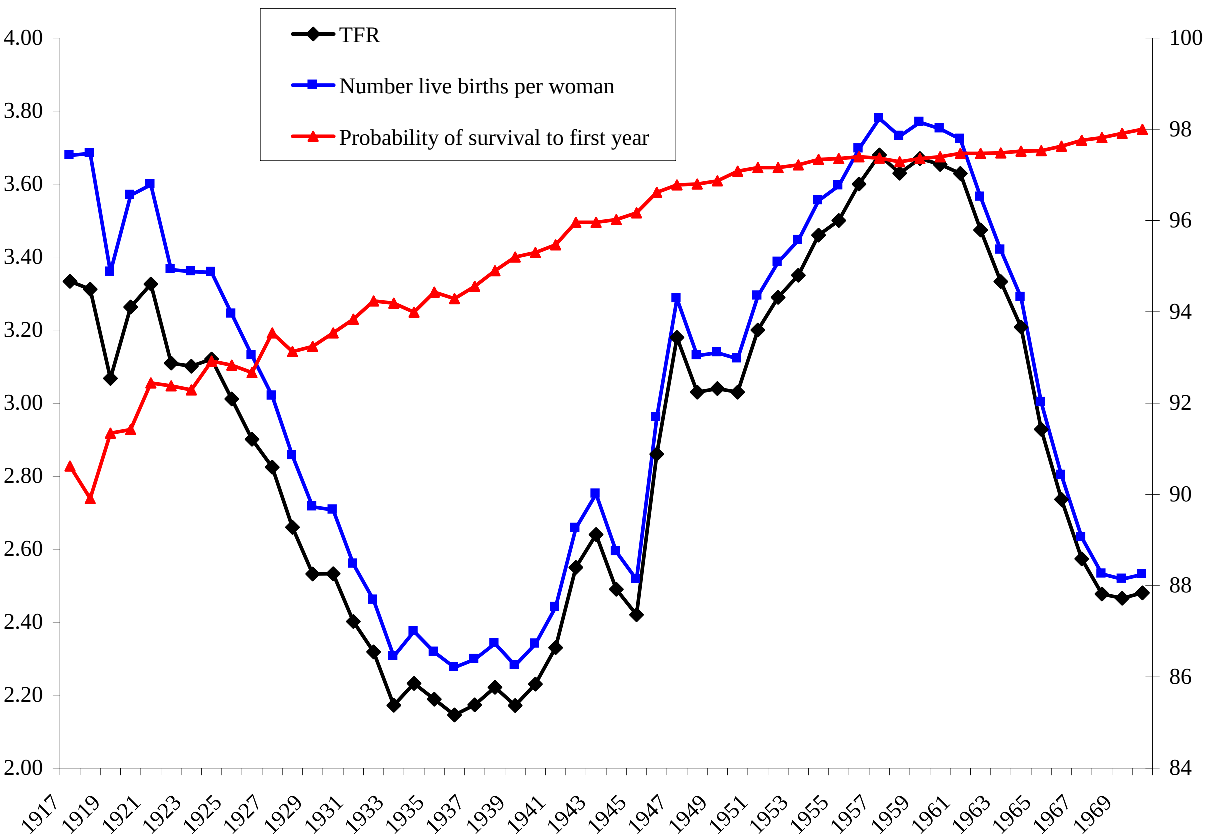


Figure 4: Determinants of the time cost of pregnancy.

in the time cost of having children, all else equal. Between 1920 and 1936, the decline in the number of live birth per woman is steeper than the decline in the total fertility rate, owing to the increase of infants' survival probability. The fluctuations in this series mainly depend on the total fertility rate since the infant mortality rate declines monotonically over this period. We use these series in our transitional simulations.

2.5 Trends in Maternal Mortality

The risk of temporary or permanent disability, and potentially death, associated with labor, delivery and post-partum conditions substantially contributed to the cost of women's maternal role, as documented in Leavitt (1986). The most debilitating ailments associated with the child bearing process were puerperal fever and other post-partum infections, hemorrhages, vesico-vaginal fistula, assorted forms of perineal lacerations, as well as a variety of complications during labor and delivery, such as pelvic deformation, lack of strength due to poor nutrition, all contributing to imperil the life of the mother, as well as that of the child. Given the difficulties in obtaining quantitative measures that systematically track medical progress in the area of maternal health, we focus on the maternal mortality rate as a proxy, plotted in figure 5. By this measure, childbirth was a very dangerous event in women's lives until the mid 1930s. In 1915, there were 60.8 maternal deaths per 10,000 live births. After a temporary rise due to the 1918 influenza outbreak, the rate of maternal deaths averaged 68 per 10,000 live births in the 1920s- a considerable number. It gradually declined to 48.9 maternal deaths per 10,000 live births in 1936, when the maternal death rate starts dropping substantially, reaching 4.7 maternal deaths for 10,000 live births in 1955.

What led to these dramatic improvements in maternal health? While rates of maternal mortality only declined substantially starting in the 1930s, the changes to the birthing process that eventually led to this outcome began in the early part of the 19th century. Until the early 1800s, only women were admitted in the birthroom and deliveries were assisted exclusively by midwives. Despite their extensive experience, midwives did not have sufficient medical knowledge to deal with the potential complications associated with parturition. Midwifery was not considered part of medical science and physicians, who were exclusively male, were not trained to deal with women's health. The first attempts to bring medical science into the birthroom date to the late 18th century when affluent families in the North-East started to invite male physicians to assist with deliveries.[19] Physicians used drugs to alleviate pain during labor, administered ergot, a drug that intensified uterine contractions hastening delivery, and often resorted to bloodletting and forceps. The introduction of anaesthetics in the birthing room increased the advantage of having medical attendants over midwives and the practice steadily grew in the second half of the 19th century. In 1900, 50% of all births were assisted by midwives and the rest by physicians.

The presence of formally trained physicians was instrumental in preventing maternal and neonatal deaths in many instances. However, the initial lack of experience and the practice of avoiding visual examination of female patients undermined their ability to intervene effectively during parturition. Trial and error experimentation and excessive operative interventions, such as episiotomy and aggressive use of forceps, were common to the point that medical records are full of examples of women whose suffering was in fact increased by the presence of medical attendants. In addition, physicians' exposure to other patients with communicable diseases actually increased the risk and incidence of post-partum infections before germ theory was widely accepted and antibiotics were available. Even if initially the intervention of physicians with formal medical training did not contribute to a substantial reduction in maternal mortality, it led to the introduction of new procedures that laid the ground for an improvement in obstetric practices that, as reported by Leavitt (1986), substantially reduced the risk of a mother suffering temporary or permanent disability following delivery during the first half of the twentieth century. The most notable developments were surgical procedures to correct perineal lacerations, first published in the 1850s, and the adoption of new hygene standards following the discoveries in bacteriology of the late 1800s.

The perceived iatrogenic nature of women's birthing and post-partum conditions in the early part of the 20th century led to the second major revolution in the practice of childbirth, the move from home to hospital. This shift was part of a broader effort in the medical profession to standardize and monitor obstetric practices, eventually leading to the establishment of American Board of Obstetrics and Gynecology in 1930. Until the mid 1920s, only poor women gave birth in hospitals and increased hospitalization actually gave rise to higher rates of maternal mortality.

[19] The first physician to devise a systematic system of lectures on midwifery for male physicians was William Shippen, who retured from studies in London and Edinburgh in 1792. The British Islands had an established tradition of men-midwives and were more advanced in the area of obstetrics and neonatal health than the US (see O'Dowd and Philipp). Shippen established a midwifery practice in Philadelphia and served established families in that city.

This has been explained as part an outcome of excessive operative interventions that also plagued home births. Hospital delivery also became appealing to an increasing number of women due to the improved quality of care within those institutions and to the possibility of receiving pain relief medication during labor. Starting in the 1930s, with the advent of electronic imaging and advanced neonatal therapies that could only be administered in a hospital setting, wealthy women also started giving birth in hospitals. In 1935, approximately 36.9% of all births took place in hospitals. By 1955, 94.4% of all births took place in hospitals.[20] Table 4 lists the major medical discoveries and innovations connected to pregnancy, labor and parturition between 1800 and 1940.

The decline in maternal mortality occurred gradually in the later part of the 1920s and precipitously starting in 1936. The surge in the rate of hospital births starting in 1935 was associated with the phase of sharply declining maternal mortality rates - from 56.8 deaths per 10,000 live births in 1936 to 4.7 in 1955, making childbirth a demonstrably safer event.[21] The improvements between 1936 and the mid 1950s can be attributed to the application of the new obstetric practices developed by trial and error in the late 1800s and early 20th century, as well as to the general availability of antibiotics and penicillin to treat infection and sepsis, and of transfusions to replace blood lost in hemorrhages. As shown in figure 5, maternal mortality rates continued to decline after 1955, but only gradually, reaching 2 deaths per 10,000 live births in 1970.[22]

Table 4: Timeline for Maternal Health

1827	First (successful) cesarean section performed in the US.
1843	Puerperal fever found contagious. Notion of prevention via hygienic measures introduced.
1852	Sims published methods for vesico-vaginal fistula repair. Additional progress in 1914 and 1928.
1861	Semmelweis published findings on preventing post-partum infections in maternity wards in Vienna.
1867	First published paper on surgical antisepsis, first clinical application of bacteriological principles.
1876	Italian surgeon develops cesarean section technique that makes the operation considerably safer.
1879	Pasteur links puerperal fever to streptococcus.
1898	X-ray pelvimetry first used for difficult obstetric cases. Becomes routine in 1930s.
1912	US Children's Bureau founded. Reveals problem of high infant and maternal mortality rates.
1915	Low cervical cesarean section developed. Significantly decreased the incidence of infection and uterine rapture.
1928	Penicillin discovered, becomes widely available at the end of WWII. Dramatically reduces deaths due to post-partum infections and cesarean sections.
1930	American Board of Obstetrics and Gynecology established.
1933	National campaign against unnecessary instrument and drug intervention during labor and delivery.
1935	Antibiotic action of sulphonamides discovered.
1936	Hospital blood banks established. Aids with post-partum hemorrhages.

We combine the information on maternal mortality rates and number of live births to obtain a measure of overall maternal mortality risk for a given completed fertility, which we will use in

[20] To summarize, there are three phases in the history of childbirth based on the most common practice: i) until 1850s, birth at home with midwife; ii) 1850-1935, birth at home with physician; iii) after 1935, birth in the hospital. See Thomasson and Treber (2004), Leavitt and O'Dowd and Philipp for further details.

[21] Source: U.S. Census Bureau, Statistical Abstracts of the United States. Mini-Historical Statistics, Table HS-13 and Guyer, Freedman, Strobino and Sondik (2000).

[22] The gradual decline continued in the following decades down to a maternal mortality rate of 0.1 per 10,000 live births in 2001.

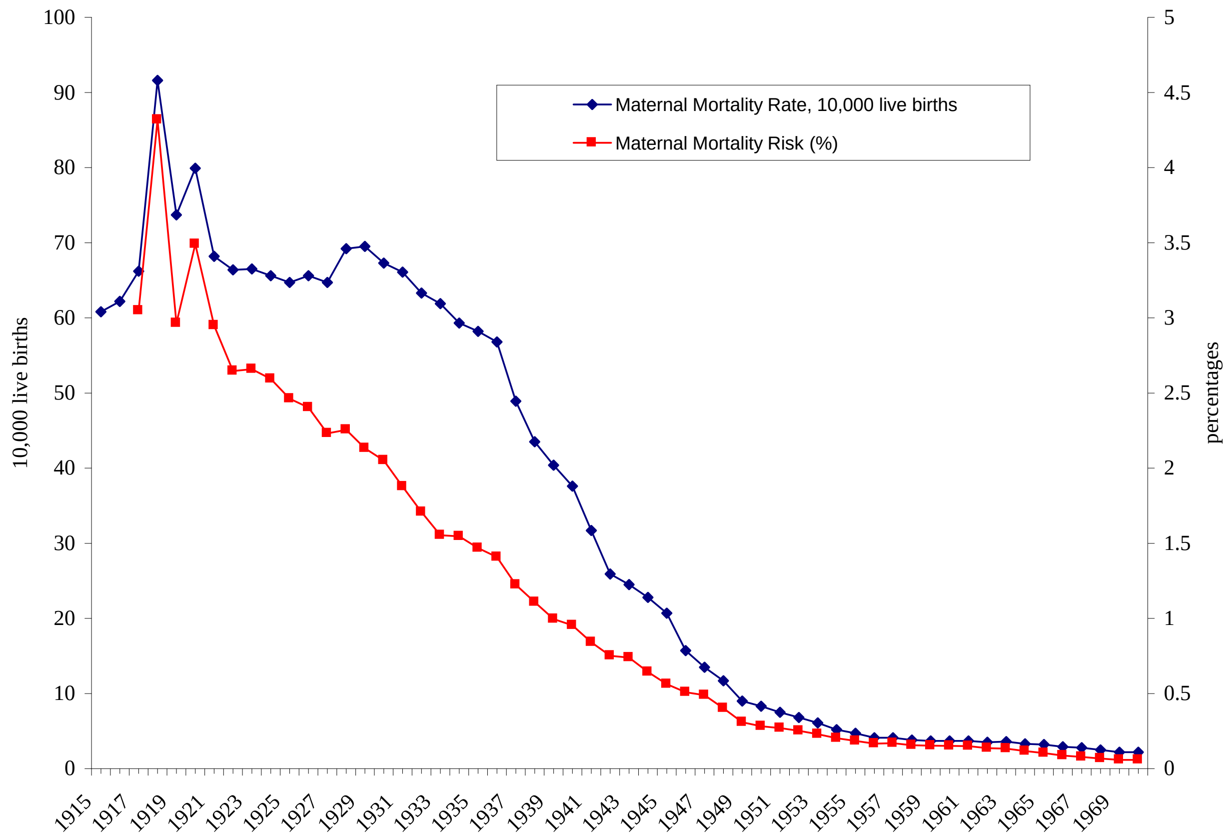


Figure 5: Trends in maternal mortality.

our quantitative experiments. In 1920, there were 80 maternal deaths per 10,000 births, that is one mother died for each 125 living births. Given that in 1920 women delivered 4.35 live babies over the course of their fertile years, a woman's risk of dying of childbirth would compound to 3.5% or 1 in 29. Repeating this calculation for each year between 1920 and 1970 we obtain the series for maternal mortality risk reported in figure 5. The risk of disability, and potentially death, associated with labor, delivery and post-partum conditions affects women in two ways. The direct effect corresponds to the reduction in women's productive time due to childbirth induced disabilities. The indirect effect is more subtle and is associated with the role that the risk of death and disability played in confining women to a more domestic role, reducing their incentives to invest in education and productive skills. Even if these effects are hard to quantify, we take this measure of the mortality risk as a proxy for their contribution to the time cost of women's maternal role.

To conclude, the medical technologies that we study in this paper underwent their largest improvements between the mid 1920s and the mid 1950s. By 1970 they had reached their modern levels and did not improve substantially thereafter. For example, improvements in infant formula, as conveyed by its time price, were not substantial after 1970. As shown in Figure 2, the time price of baby formula, per liquid "ready-to-feed" ounce, remained fairly constant between 1970 and 1985. In addition, the decline in infant mortality rates (and maternal mortality rates) had plateaued by the 1970s. Since we want to study the impact of these technologies on women's outcomes, we concentrate on the pre-1970 period.

3 Model

We assume the economy is populated by overlapping generations of agents who live for three periods or ages, r, with $r = 0, 1, 2$. Each generation comprises a continuum of agents who differ in their labor productivity in the market sector, ξ, and by gender. Cohorts and the overall population are split equally by gender and the distribution of labor market productivity is the same across genders. In the first age of their life, all agents are single. They all marry in the second period of their life to an agent of different gender and with the same labor productivity and remain married in the third period. In each time period, t, a new generation of young agents is born, of the same size. Hence, total population size is constant.

In all periods, agents value private consumption, c, leisure, l, and a home good G. The home good, G, represents *general household goods* (and services), such as meal preparation, cleaning, helping children with homework, vacation planning, yard work and other activities. While agents value general household goods at all ages, their preferences over this good may be age dependent. In the first period of marriage and only in that period, agents also derive utility from an additional home good I. We refer to I as the *infant good*, which corresponds to those goods and services that are related to the existence of infants in the household, that is children between 0 and twelve months. Hence, the first period of marriage corresponds to the fecund period of life. Home goods are public within the household when agents are married.

Individual preferences can be represented by the following lifetime utility function:

$$\sum_{r=0,1,2} \left(\prod_{s=0}^{r} \beta_s \right) u\left(c_r, l_r\right) + g_0\left(G_0\right) + \beta_1 g_1\left(G_1, I_1\right) + \beta_1 \beta_2 g_2\left(G_2\right),$$

where

$$u\left(c, l\right) = \frac{c^{1-\sigma}}{1-\sigma} + v\left(l\right),$$

and $v\left(l\right)$ represents the sub-utility from leisure:

$$v\left(l\right) = \psi_0 \frac{l^{1-\psi}}{1-\psi}.$$

Leisure is defined as:

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

where T is the individual time endowment, $p \in [0, 1]$ denotes labor force participation, $\bar{n}$ corresponds to the fixed number of work hours an employed individual works on the market and $\sigma, \psi_0, \psi \geq 0$. In addition, $\beta_r \in (0, 1)$ represents the discount factor from age r to age $r-1$. with $\beta_0 = 1$. We allow for differential discount factors to accommodate ages of different duration.

We now describe in detail the production technology for the home goods.

3.1 Home Production

For each good, both time and market goods are inputs in production. The key assumption is that women and men can equally contribute to the production of general household goods. Instead, only the wife's time is used as an input in the production of infant goods. This asymmetry is clearly extreme, since the husbands' contribution to the production of infant goods is necessary, at least at conception. However, it provides a simple and realistic way of modelling women's comparative advantage in the production of infant goods, based on the fact that *only* women can give birth and breast-feed. The ratio of home hours to market goods in production depends on the technology. There are two technologies for the production of each home good, an *old* and a *new* technology. The new technologies are less time intensive than the old. The old technologies are free, while the new technologies are costly. The fixed cost of adoption for the new home technologies is a time price that corresponds to the monetary value of the market goods associated with the new production technologies translated into units of time. The time price of the new technologies can change over time. A decline in the time price of the new technologies reflects technological progress embodied in the market goods used in the production of each home good. Households choose which technology to adopt for each home good in each period of their life.

3.1.1 Infant Goods

The infant goods are produced exclusively using the wife's time. Under the old technology, this is the only input of production. The level of production of infant goods under the old technology is given by:

$$I(0) = \min\left\{\nu_I \rho_I, h^{fI}(0)\right\}, \tag{1}$$

where $h^{fI}(0) = \rho_I \nu_I > 0$ denotes the time required by the wife to produce I. The level of production of the infant good under the new technology is:

$$I(1) = \rho_1 \min\left\{\nu_I, h^{fI}(1)\right\}, \tag{2}$$

with $\rho_I > 1$. The parameter ρ_I represents the time saving associated with adoption of the new I technology, with $h^{fI}(0) = \rho_I \nu_I > h^{fI}(1) = \nu_I$. The quantity $\rho_I \nu_I$ under the new technology can be interpreted as the quantity of market goods associated with the production of the infant good, such as infant formula. The parameter ν_I corresponds to the time cost of pregnancy and is present even if the new technology is adopted. The old technology is free and we denote the price of the new technology with q^I. Note that $I(0) = I(1)$, so that the two technologies deliver the same level of output. Hence, the only advantage of the new technology is that it reduces the wife's required time in the production of infant goods.

A few words of interpretation are in order here. The total time devoted by wives to the production of infant goods represents the sum of feeding time plus the time associated with pregnancy, childbirth and recovery. This is based on the notion that a pregnancy is associated with a physical cost that reduces a woman's ability to perform market work. The parameter ν_I measures this cost in equivalent time units. Under our interpretation, breast-feeding is the *only* way to feed infants under the old technology, while under the new technology infants are fed formula with a bottle. The parameter ρ_I corresponds to the time saved by the mother with formula feeding relative to nursing. Based on our discussion of the empirical evidence on infant feeding and obstetric practices, we model bottle feeding infants as a choice. On the other hand, most households were just confronted with "best" practices for behavior during pregnancy, childbirth and recovery, which they took as given. Hence, the time cost of pregnancy ν_I is a parameter of the I technology. To incorporate the effects of the reduction in the physical cost of pregnancy over time we will allow ν_I to be time dependent. In particular, the value of ν_I will reflect progress in medical knowledge and obstetric practices, leading to healthier pregnancies, quicker recovery from labor and lower maternal and infant mortality, as well as to historical changes in fertility. Finally, the assumption that $I(1) = I(0)$ is based on our interpretation of formula feeding and improvements in medical care of mothers and infants as a way to deliver the same amount of infant good, and therefore utility, at a smaller time cost for women[23].

Under our interpretation, the new technology allows infant feeding, that under the old technology can only be produced by the mother, to become a general household good that could be produced by both spouses. The mother's time required for infant feeding drops to zero under the new technology, since both the mother and the father, or a child care provider, can bottle feed. Hence, there is no difference between bottle feeding an infant and general household goods, such as helping children with homework or meal preparation, in terms of comparative advantage by gender. We therefore assume that when a household adopts the new technology for producing infant goods this increases the time required for general good production by the amount $\nu_I(\rho_I - 1)$, which corresponds to the fraction of time devoted to breast-feeding by mothers in households that use the old technology to produce the infant good. However, the asymmetry in the spouses' contribution to the production of the infant good I remains under the new I technology since mothers still have to "pay" the physical cost of pregnancy ν_I.

We now describe the technology for production of the general household goods.

3.1.2 General Household Goods

Our model for general household good production is similar to Greenwood, Seshadri, and Yorugoklu (2005), henceforth GSY. The production function for *singles* and *old married households* is $G(\tau^G)$:

$$\begin{aligned} G(0) &= \min\{\rho_G \nu_G, H(0)\}, \\ G(1) &= \rho_G \min\{\nu_G, H(1)\}, \end{aligned} \tag{3}$$

where $\tau^G = 0, 1$ denotes whether the old ($\tau^G = 0$) or the new ($\tau^G = 1$) technology is used. The variable d represents market goods that are used in the production of G, such as home appliances or groceries. The variable H represents the contribution of home hours to the production of the home good. For married households, this is given by:

$$H = \left[0.5\left(h^{fG}\right)^{\zeta} + 0.5\left(h^m\right)^{\zeta}\right]^{1/\zeta}. \tag{4}$$

where the parameter ζ determines the substitutability of husbands' and wives' home hours in the production process. Hence, spouses contribute symmetrically to the production of G, irrespective

[23] Given that I represents infant goods, it can be broadly interpreted as being positively related to the quantity/quality of children within the households. If $I(1) > I(0)$, the adoption of the new technology would also correspond to an increase in the number/quality of infant within the household. We do not pursue this interpretation, since we treat fertility as exogenous in this version of the paper.

of the technology used. The parameter ζ determines the substitutability of spousal home hours in the production of G.

The parameter $\rho_G > 1$ denotes the time savings associated with the new G technology, so that the new technology requires fewer home hours, that is $H(0) = \rho_G \nu_G > H(1) = \nu_G$. We denote with q^G the time price of the new home durables technology, which reflects the market value of the market goods associated with the new G technology, such as home appliances, groceries etc. The old technology is free.

For *young married households*, we incorporate the complementarity between infant and general household good production in the following way:

$$\begin{aligned} G\left(0, \tau^I\right) &= \min\left\{\rho_G \nu_G, H\left(0, \tau^I\right)\right\}, \\ G\left(1, \tau^I\right) &= \rho_G \min\left\{\nu_G, H\left(1, \tau^I\right)\right\}, \end{aligned} \tag{5}$$

where $H\left(0, \tau^I\right) = \rho_G \nu_G + \tau^I \nu_I (\rho_I - 1)$ and $H\left(1, \tau^I\right) = \nu_G + \tau^I \nu_I (\rho_I - 1)$, and $\nu_I (\rho_I - 1)$ is the time required for infant feeding if the new I technology is adopted and thus this service becomes a general household good.

We now describe the agents' optimization problems at each age in life.

3.2 Single Agents' Problem

Agents are born with no wealth and cannot borrow against future income. At age 0, they are single. They decide on whether to participate in the labor force in that period, on whether to acquire market skills, on production of the home good G and on how much to save. The acquisition of market skills has a time cost of $\gamma > 0$ and affects their labor market productivity at ages $r = 1, 2$, as follows:

$$\xi^j = \xi\left(1 + \varepsilon e^j\right), \tag{6}$$

where the parameter ε represents the returns to skills and $e^j = 0$ when no skills are acquired and $e^j = 1$ otherwise.

A single individual's problem is:

$$\Pi_0^j(\xi) = \max_{a_1^j \geq 0, p, e \in \{0,1\}, \tau^G} u\left(c, T - e\gamma - h\left(\tau^G\right) - p\bar{n}\right) + g_0\left(G\left(\tau^G\right)\right) + \beta_1 \Pi_1^j\left(a_1^j, e; \xi\right), \tag{Problem S}$$

subject to (6), (3) and:

$$c + a_1^j \leq w\left(\xi p - \tau^G q^G\right),$$

for $j = f, m$. Here, $\Pi_1^j\left(a_1^j, e; \xi\right)$ denotes the maximized present discounted value of individual lifetime utility at the beginning of period 1, which will be derived below. The variable w denotes economy-wide real wages in efficiency units of labor and may change over time, due to improvements in the market production technology.

3.3 Household Problem

We model married individuals according to Chiappori's (1988, 1997) *collective labor supply* approach. Under this paradigm, household decisions are Pareto efficient. Households choose a sequence of private consumption, participation, and home hours for each spouse, as well as technologies for the production of the home goods, subject to an intertemporal budget constraint and to the technological and feasibility constraints.[24]

We first describe the optimal choice of home hours in each period, taking as given the technology for the production of the public home goods. This step corresponds to solving the following cost minimization problem:

$$C\left(\bar{H}, \bar{h}^{fI}\right) = \min_{h^m \in \left[0, \bar{h}\right], h^{fG} \in \left[0, \bar{h} - h^{fI}\right]} \xi\left(1 + \varepsilon e^f\right) h^f + \xi\left(1 + \varepsilon e^m\right) h^m$$

subject to

$$h^f = h^{fI} + h^{fG},$$

$$\left[0.5\left(h^m\right)^\zeta + 0.5\left(h^{fG}\right)^\zeta\right]^{1/\zeta} \geq \bar{H},$$

$$h^{fI} \geq \bar{h}^{fI},$$

for some $\bar{H} = H\left(\tau^G, \tau^I\right)$ and $\bar{h}^{fI} = h^{fI}\left(\tau^I\right)$.

The first order necessary conditions for h^{fG} and h^m for interior solutions are:

$$\frac{\xi\left(1 + \varepsilon e^f\right)}{\left(h^{fG}\right)^{\zeta - 1}} = \frac{\xi\left(1 + \varepsilon e^m\right)}{\left(h^m\right)^{\zeta - 1}}, \tag{7}$$

$$\left[0.5\left(h^m\right)^\zeta + 0.5\left(h^{fG}\right)^\zeta\right]^{1/\zeta} = \bar{H},$$

$$h^{fI} = \bar{h}^{fI}.$$

We will denote with $h^j\left(\tau^G, \tau^I\right)$ for $j = f, m$ the policy functions for the cost minimization problem. By (7), if $e^f = e^m$, then, the solution is $h^{fG} = h^m$. If instead $e^f \leq e^m$, then, the only solution has $h^{fG} > h^m$.

Let Z_t denote total household expenditures net of total household income in period t. Then:

$$\begin{aligned} Z\left(\tau^G, \tau^I; q^G, q^I, w\right) &= \sum_{j=f,m}\left[c^j + \xi^j l^j\right] + w\left[C\left(H\left(\tau^G\right), h^{fI}\left(\tau^I\right)\right) + q^G\tau^G + q^I\tau^I\right] \\ &\quad -Tw\sum_{j=f,m}\xi^j. \end{aligned}$$

Substituting in the expressions for the cost of production of the two public goods, we obtain:

$$Z\left(\tau^G, \tau^I; q^G, q^I, w\right) = \sum_{j=f,m} c^j + w\left(q^G\tau^G + q^I\tau^I\right) - w\sum_{j=f,m}\xi^j p^j \bar{n},$$

[24] The Pareto problem can be decentralized by allowing each spouses to individually choose labor force participation and private consumption in each period. Households then jointly choose a rule for sharing household wealth, savings, the allocation of home hours and the technologies for producing the home goods. The fact that saving is a joint household decision implies that individual problems are static. Moreover, the household is implicitely assumed to have commitment in the joint choices.

where w corresponds to the contemporaneous value of economy-wide real wages. Hence, the household's intertemporal budget constraint is given by:

$$Z_1\left(\tau_1^G,\tau_1^I;q_1^G,q_1^I,w_1\right)+\frac{Z_2\left(\tau_2^G,\tau_2^I;q_2^G,q_2^I,w_2\right)}{1+R_2}\leq a_1, \tag{8}$$

where a_1 is household wealth at the beginning of age 1[25]. The households initial wealth a_1 is given by the sum of the spouses' wealth at the beginning of age 1, $a_1=\left(a_1^f+a_1^m\right)(1+R_1)$, where the values of a_1^j solve the spouses' individual optimization problem when single.

The households' Pareto problem is given by:

$$\max_{\tau_1^I,\left\{c_r^j,p_r^j,\tau_r^G\right\}_{r=1,2,j=f,m}}\sum_{r=1,2}\beta_2^{r-1}\sum_{j=f,m}\lambda_j u\left(c_r^j,T-h_r^j\left(\tau_r^G,\tau_r^I\right)-p_r^j\bar{n}\right)+g_1\left(G_1\left(\tau_1^G\right),I_1\left(\tau_1^I\right)\right)+\beta_2 g_2\left(G_2\left(\tau_2^G\right)\right)$$

subject to (8) and (3), (1)-(2), (6), with $e_r^j=0$ for $r=1,2$, $h_2^{fI}=0$ and $h_2^f=h_2^{fG}$ and where λ_j $j=f,m$ denote the spouses' Pareto weights.

Since at age 2 the infant good is not valued, it will not be produced, and $\tau_2^I=0$ and $h_2^{fI}=0$, so that $h_2^f=h_2^{fG}$. Given the lumpy nature of the choice of τ_r^G and τ_1^I, and the fact that home hours are determined by the cost minimization problem as a function of technology, the only first order necessary conditions for the household problem are:

$$\lambda_j u_{c,1}^j-\mu=0, \text{ for } j=f,m, \tag{9}$$

$$\lambda_j\beta_2 u_{c,2}^j-\mu\left(1+R_2\right)=0, \text{ for } j=f,m, \tag{10}$$

$$\lambda_j u_{l,1}^j-\mu w_1 e^j=0, \text{ for } j=f,m, \tag{11}$$

$$\lambda_j\beta_2 u_{l,2}^j-\mu\left(1+R_2\right)w_2 e^j=0, \text{ for } j=f,m, \tag{12}$$

for given values of G_r, I_1, τ_r^G and τ_1^I, as well as the intertemporal budget constraint (8). Here, μ is the multiplier on the intertemporal budget constraint.

The intertemporal pattern of consumption is independent from the distribution of the Pareto weights or the choice of technology and labor force participation patterns over time. Instead, the higher the Pareto weight of a spouse, the higher the optimal level of consumption and leisure. It follows that p_r^j is decreasing in λ^j coeteris paribus, so that wives will participate more if their Pareto weight is lower.

The Euler equation for the individual saving choice at age 0 is:

$$-u'\left(p_0^j\xi-a_1^j,T-\gamma e_0^j-p_0^j\bar{n}\right)+\beta_1\Pi_{1,a}^j\left(a_1^j,e;\xi\right)\begin{cases}\leq 0,\\ =0 \text{ for } a_1^j>0.\end{cases} \tag{13}$$

The envelope condition for this problem is:

$$\Pi_{1,a}^j\left(a_1^j,e;\xi\right)=\frac{\mu}{\lambda_j}, \text{ for } j=f,m. \tag{14}$$

Intuitively, a spouse with a higher Pareto weight will obtain a larger share of resources when married and finds it optimal to bring lower wealth levels into the marriage, other things equal.

[25] Here, the home goods are not marketable, so their production level does not enter in the household budget constraint. See Chiappori (1997) for a discussion.

Here, as previously noted, $\Pi_1^j\left(a_1^j, e; \xi\right)$ is the maximized present discounted value of lifetime utility at the beginning of period 1. Given that this corresponds to the individual value function for the household's optimization problem, it is possible to incorporate the agent's problem when single into the household problem, to simplify the derivation of lifetime consumption, home hours and participation paths. We describe this strategy of solving the household problem in detail in the Model Appendix.

3.4 Market Production and Equilibrium

A continuum of identical, perfectly competitive firms in each period produce an undifferentiated output using labor only, and then convert it into consumption goods and goods used in the production of general household and infant goods.

The representative firm produces the undifferentiated output, Y, according to the production function:

$$Y \leq \Xi N, \tag{15}$$

where the variable Y denotes per capita production of the undifferentiated good and N is per capita (average) labor input in efficiency units, given by:

$$N = \int_i p(i)\, \xi_i \left(1 + e_i\right) d\Gamma(i), \tag{16}$$

where i indexes individuals in the population. Here, Ξ corresponds to average labor productivity. Ξ may grow over time to reflect technological advancements in market production. Y can be transformed into home durables, D, commodities used in the production of infant goods K, and private consumption goods, C, according to the technology:

$$\gamma^G D + \gamma^I K + C \leq Y. \tag{17}$$

Given that all technologies are constant returns to scale and that the production sector is competitive, $w = \Xi$ in equilibrium, so that wages will grow one to one with market productivity. In addition, competitive pricing pins down the equilibrium values of q^l as a function of the technological marginal rates of transformation γ^l, for $l = G, I$.

We describe the representative firm's problem and the derivation of the equilibrium in the Model Appendix.

4 Quantitative Analysis

We calibrate parameters to match the equilibrium of our model to a variety of data statistics in 1920. We then simulate the transition between 1920 and 1970 predicted by the model, by feeding in the corresponding technological progress in households technologies as proxied by the decline in the time price of home durables and infant formula over this period. Finally, we run several experiments to gauge the contribution of the introduction of new general household and infant goods technologies on the equilibrium allocation.

4.1 Calibration

We set $\lambda_f = \lambda_m = 0.5$ so that spouses have equal bargaining power. We adopt the following specifications for utility over public home goods:

$$g_1(G, I) = \theta_G \log(G) + \theta_I \log(I),$$

$$g_r(G) = \theta_G \log(G) \text{ for } r = 0, 2,$$

and set $\theta_G = \theta_I$. We fix $\sigma = 1$ and $\psi = 1$, so that utility is logarithmic in private and public consumption. This implies that wealth and substitution effects of changing new technology prices and aggregate wages exactly cancel.

We calibrate the remaining parameters to match certain data statistics of interest in 1920.

We interpret the single period as covering ages 15-22, and the second period as covering ages 23-33, based on the fact that the median age at first birth for women is 22.9 in 1920, while the median age at last birth is 33.[26] We consider the last period as corresponding to ages 34-60, where we assume that 60 corresponds to retirement. We set the yearly interest rate at 5%, and fix $\beta_1 = \exp(-0.05 * 7)$ and $\beta_2 = \exp(-0.05 * 13)$, with $R_r = 1/\beta_r - 1$ for $r = 1, 2$.

We calibrate the parameters of the G technology as follows. Given our assumption that spouses have a symmetric role in the production of G, we allow for high substitutability between home hours of wives and husbands, and we set $\zeta = 0.9$. This corresponds to an elasticity of substitution between husbands' and wives' home hours in the production of G equal to 10.0. We set the parameters ρ_G and ν_G based on the assumption that all households in which the wife participates in the labor force adopt the new technologies in 1920. Using the value of home hours of married women, conditional on participation in the labor force, and of married men in 1920, this delivers:

$$\rho_G \nu_G = \left[0.5 * \left(\frac{4}{112}\right)^{\zeta} + 0.5\left(\frac{51}{112}\right)^{\zeta}\right]^{1/\zeta} = 0.2346,$$

$$\nu_G = \left[0.5 * \left(\frac{4}{112}\right)^{\zeta} + 0.5\left(\frac{25}{112}\right)^{\zeta}\right]^{1/\zeta} = 0.1256,$$

which implies $\rho^G = 1.87$.

We set the parameters for the infant good technology in 1920 as follows. The parameter ν_I to corresponds to the time cost of pregnancy, childbirth and recovery as a fraction of the time endowment, and the parameter ρ_I to correspond to the time saving associated with bottle feeding relative to breast-feeding. Based on the calculations described in Section 2 we have that a woman would spend a fraction:

$$\nu_I(1920) = \frac{(TFR_{1920}/Sprob_{1920}) * (3/12)}{33 - 23}$$

of her time endowment in period 1 pregnant and a fraction $\frac{TFR_{1920} * (17/112)}{33-23}$ nursing, so that:

$$\rho_I(1920) = \frac{\nu_I(1920) + TFR_{1920} * (17/112)/(33 - 23)}{\nu_I(1920)}.$$

[26] See appendix for data sources.

Based on $TFR_{1920} = 3.26$, infant survival probability $Sprob_{1920} = 0.91$, this implies $\nu_I = 0.1236$ and $\rho_I = 1.3335$.

Agents in our model need to know the evolution of economy-wide wages, w, and new home technology prices, q^I and q^G, to solve their decision problems. To compute the equilibrium in 1920, we assume that agents forecast future values of new technology prices and wages based on their expectation for the rate of growth of each of these variables. We then take this expectation to correspond to the average annual rate of change of the data counterparts of these variable over the time period 1920-1970. As discussed in Section 2, we adopt the notion that technological progress in the infant good is embodied in the market goods used in its production under the new technology and will be reflected in their time price. So we take the time price of the new I technology, q^I, to correspond to the time price of Similac, constructed as described in the appendix. The average yearly rate of decline for this variable is 5.08% between 1920 and 1970.

We adopt a similar strategy for general household goods. We posit that technological progress in the general household good is embodied in home durables, a decline in their time price is a measure of such progress. We then proxy q^G, the time price of the new general household technology in our 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 as a measure of real wages.[27] The average yearly rate of decline in this variable is 4.62%, without adjusting for reduced repair and energy costs, and 6.3% with these further adjustments. We adopt the former price index given that we have not performed a quality adjustment for infant formula and given that for most of the appliances the reduction in energy and repair costs occurs outside the period of interest - in the 1970s. The average yearly growth rate of our measure of real wages is 2.2%.

We calibrate the relative price of the new home technologies, the ratio q^I/q^G, as follows. From our estimates, the yearly cost of using infant formula in the 1930's, depending on the weight and sex of the infant, ranges between \$85 and \$105 at 1936 dollars. We take 100\$ as a benchmark. We then collect information on the price of appliances. From Cowan (1983) and General Electric Catalogues, the cheapest model or refrigerators sold at \$450 dollars in 1924, whereas the latest model Frigidaire refrigerator sold for 714\$ in 1922. The price of the most recent model of Maytag electric washing machine was 165\$ in 1922. The first information of the price of a vacuum cleaner dates to 1947 when the most recent Hoover model sold for 249.50\$. To estimate q^I/q^G, for each appliance we convert the first available price to 1920 dollars and we deflate it back to 1920 using the average rate of growth for the time price of home durables between 1920 and the first year the price of a particular appliance is available. We assume that a household who adopts the new G technology purchases a refrigerator, a washer and a vacuum cleaner and that the appliances need to be replaced every 5 years. Thus, a household must replace them twice in the young married period. The replacement cost corresponds to their price in the year of replacement, computed using the series for the price of home durables. Similarly, we convert the cost of feeding one child with infant formula to 1920 dollars. The ratio of the cost of feeding one child with infant formula and the cost of buying the three major home appliances in 1920 is 0.084. We then multiply this ratio by the total fertility rate in 1920, which is equal to 3.26. This delivers: $q^I/q^G = 0.27$.

We assume the distribution of ξ is log-normal, with mean $\bar{\xi}$ and standard deviation σ_ξ. This leaves seven remaining parameters: q^G, ε, γ, θ, ψ_0, $\bar{\xi}$ and σ_ξ. which we calibrate to match the value in 1920 of the following seven population statistics: home hours of married women who participate

[27] Once again, for all series we use as a deflator the CPI-U with base 1982-1984. For hourly wages, we use series Ba4361 from the Historical Statistics of the United States: Millennial Edition (2006). Details about the construction of the price series for home durables are in the appendix.

in the labor force, home hours of married women who do not participate in the labor force, home hours of men, the average rate of adoption of new general household technologies, the average rate of bottle feeding, and labor force participation of married women by cohort as a ratio to the labor force participation of men. Specifically, our target for the labor force participation of old married women in our model is the labor force participation rate in 1920 of white married women born between 1866 and 1885 over the labor force participation of men in 1920. Our target for the labor force participation of young married women in our model corresponds to the participation rate in 1920 of white married women born between 1886 and 1895 over the labor force participation of men in 1920. We select the parameterization that minimizes the sum of squares of the distance of the values predicted by our model for those parameters and the corresponding data statistic. The population statistics and the corresponding model values are listed in Table 2. The calibrated parameters are reported in Table 3.

Table 5: Calibration Targets

Population Statistic	Value in 1920	Model Value
Home hours of married women who do not participate in the labor force	51	49
Home hours of married women who participate in the labor force	25	22
Male home hours	4	7
Average adoption of new general household technology	7%	8%
Average adoption of bottle feeding technology	15%	15%
Labor force participation of young married women	9%	9%
Labor force participation of old married women	6.5%	6.5%

The data on labor force participation of married women by cohort in 1920 is reported in Goldin (1990). The 1920 targets for home hours by gender and employment status of wives are described in the Data Appendix. In order to obtain the targets in model units, we simply divide the 1930s statistics for home hours per week by 112, the non-sleeping hours per week. We rescale the home hours targets in model units, based on 112 non-sleeping hours per week and a 40 hour workweek: $T = 1$, $\bar{n} = 0.36$, $h_G^f = 0.456$ for wives who do not participate in the labor force, $h^f = 0.223$ for wives who participate, and finally $h^m = 0.0357$ for husbands. The target value of 15% for the adoption rate of the new infant feeding technology is based on the fact that, as discussed in Section 2.2, approximately 85% of infants were breast-fed in 1920. The target value of 7% for the adoption rate of new general household goods technologies is based on an average of the percentage of households with washing machines, refrigerators and vacuum cleaners, from Bowden and Offer (1994).

Table 6: Calibrated Parameters

σ, ψ	1	q^G	1.6
ζ	0.9	q^I/q^G	0.27
ν_G, ρ_G	0.1256, 1.87	ε	0.25
ν_I, ρ_I	0.1236, 1.33	γ	0.08
β_1, β_2	0.74, 0.41	θ	0.1
$\{\xi, \sigma_\xi\}$	$\{3.6, 0.7\}$	ψ_0	1.54

4.2 Equilibrium at 1920 Prices

We now discuss some key features of the equilibrium allocation for 1920. All men participate in the labor force and invest in market skills, and all single women participate in the labor force. All single men adopt the new general household goods technology, while only a fraction of single women do. Instead, male home hours are highest when single. Labor force participation of married women and investment in market skills are increasing in productivity and decreasing in age in the cross-section, though for married women, their participation is higher when old than when young. Home hours devoted to the production of G goods are highest for young married women, followed by old married women and by single women. Home hours of women are decreasing in productivity and female and male home hours in a given cohort converge as productivity increases. This is due to the fact that adoption of new home goods technologies is increasing in productivity.

The labor force participation of wives is strongly linked to the adoption of new technologies for both home goods at age 1 and with the adoption of the new technology for the public good at age 2. The adoption of new home goods technologies is necessary for married women to participate in market work, as participation of the wife occurs only for households that have adopted both new technologies. Adoption of the new I technology, which occurs at lower levels of productivity, given its' lower price, increases the incentive to adopt the new G technology, since it increases the demand for general household goods.

The female/male earnings ratio in the model depends on the relative investment in skills across genders. Investment in market skills is lower for the older cohorts of women in the model, leading to a lower female/male earnings ratio for the old cohort relative to the young generation. This cohort effect stems from the fact that the old married cohort faces higher prices for the new home technologies and lower real wages. This leads to lower adoption rates at both ages of marriage and, therefore, lower participation of women when married. The reduced returns to investment in market skills determines lower investment rates when single. This property of the model is consistent with empirical evidence for the US that average gender wage differentials are increasing with age and higher for older cohorts.[28]

As is clear from Table 2, the model predicts higher home hours for men, relative to the data. This is due to the fact that all married women who participate in the labor force belong to households that have invested in the new technologies and most of them invest in market skills. Hence, they have the same wage as their husbands and the allocation of home hours devoted to the production of G goods is symmetric in those households.

4.3 Transition

Our model features four exogenous sources of technological change. The first is the increase in economy wide labor productivity, due to technological progress in market good production, reflected in the average real wage. The second is the improvement in general household technologies as reflected in the decline in the time price of these technologies. These factors influence the opportunity cost of home production for both genders. Third, the introduction of time-saving infant

[28] In the data, there is not a substantial difference in average years of formal schooling across genders for the period, though the statistic is slightly lower for women. Median years of school completed by people 25 and over are equal to 8.6 for men and 8.7 for women in 1940. See Table A1 - http://www.census.gov/population/www/socdemo/educ-attn.html. In our interpretation, investment in market skills in the model does not precisely correspond to formal schooling, but to effort exerted in early labor market experiences that may influence future carrier paths and earning potential.

feeding technologies and their improvement over time, reflected in the decline in the time price of breast-milk substitutes. Lastly, a reduction in the time cost of pregnancy driven by improved medical practices and knowledge leading to lower infant and maternal mortality rates, as well as by changes in fertility. The third and fourth factor have a direct impact on women only.

To evaluate the role of these factors on the dynamics of married women's labor force participation, as well as on other important variables, such as the female/male earnings ratio, home hours and women's investment in market skills, we construct measures of these variables for the time period between 1920 and 1970 and feed them into the model to examine the properties of the transition.

We adopt the measure of real wages used in the calibration to proxy the improvement in economy-wide labor productivity. We use the real value of Gordon's (1990) quality-adjusted Divisia price index for eight appliances, rescaled by real wages as a measure the time price of new general household technologies. This price series is available starting only in 1947. We use the time price of Similac as a proxy for the time price of the infant goods technology, which is available since 1935. We extrapolate the two price series back to 1920 using the average yearly price change between 1935 and 1985 for infant formula and the methodology developed by Cummins and Violante (2002) for home durables (see Data Appendix for details). Finally, we estimate the variation over time in the time cost of pregnancy and in the time savings associated with formula feeding following the strategy used in the calibration. Thereby, we set:

$$\nu_I(t) = \tilde{MM}_t \frac{(TFR_t/Sprob_t) * (3/12)}{33-23},$$

$$\rho_I(t) = 1 + \frac{TFR_t * (17/112)}{(33-23)\,\nu_I(t)},$$

where TFR_t is the total fertility rate at time t and $Sprob_t$ the the probability of survival to one year of age at birth at time t. Here, $\tilde{MM}_t = MatMort_t/MatMort_{1920}$, where $MatMort_t$ is the maternal mortality rate at time t. We take the variable $\tilde{MM}_t$ as an index of progress in medical technologies leading to lower rates of death and disability for mothers, thus reducing the time cost of pregnancy.

Figure 6 plots the transitional forces at work in our model over the period of interest. We simulate the transition in our model and run several experiments to evaluate the impact of each force in isolation. Consistent with our calibration strategy, we assume that agents forecast the change in new technology prices and real wages over their lifetime using the yearly average change over the period of interest. Our results for the transition are displayed in figure 7, where the solid red lines correspond to data and the dashed black lines correspond to model predictions.

The model over predicts the rise in the labor force participation of young married women and in the adoption of the new infant good technology. By 1970, 77% of all young married women participate in the labor force when young (dashed-line in panel 5), and 93% of young married households adopt the new infant good technology (panel 1), whereas in the data only 47% of young married women participate and the formula feeding rate is 75%.[29] This outcome is due to the

[29] We compute period average by cohort in the model simulations. This is required since the young married period lasts 11 years, the old married period lasts 27 years, which is longer than the 10 year time interval we adopt for our simulations. Hence, when we compute the transition, 1/11 agents that were young in 1920 will still be young in 1930. Similarly, 7/27 agents that were old married in 1920 will still be old married in 1940, 10/27 will still be old married in 1930. To take this into account in the transition, we treat 1920 as if everybody is a new single agent, a new young married agent and a new old agent, consistent with our calibration. In 1930 we compute all the decisions

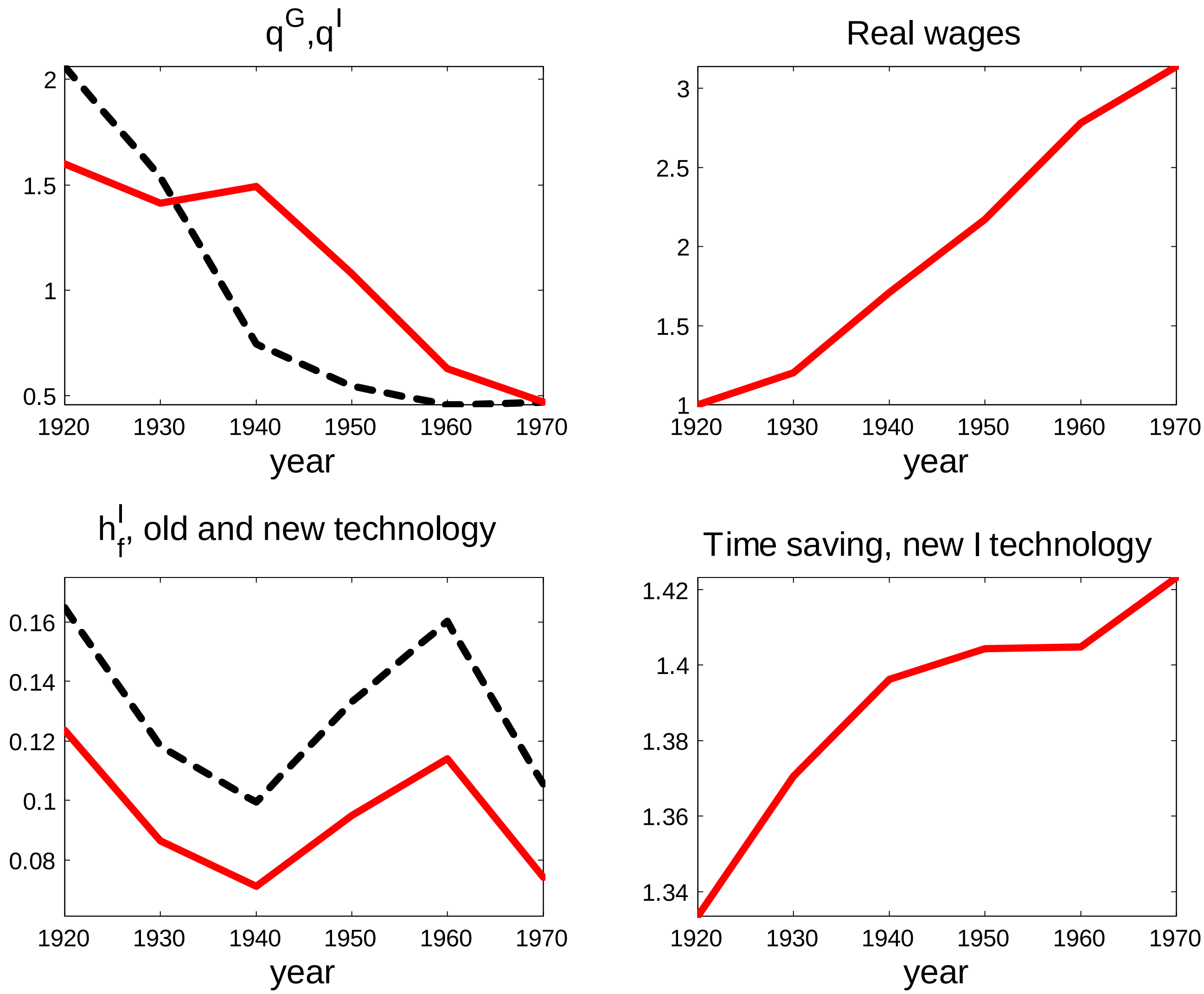


Figure 6: Forces of technological progress in the model.

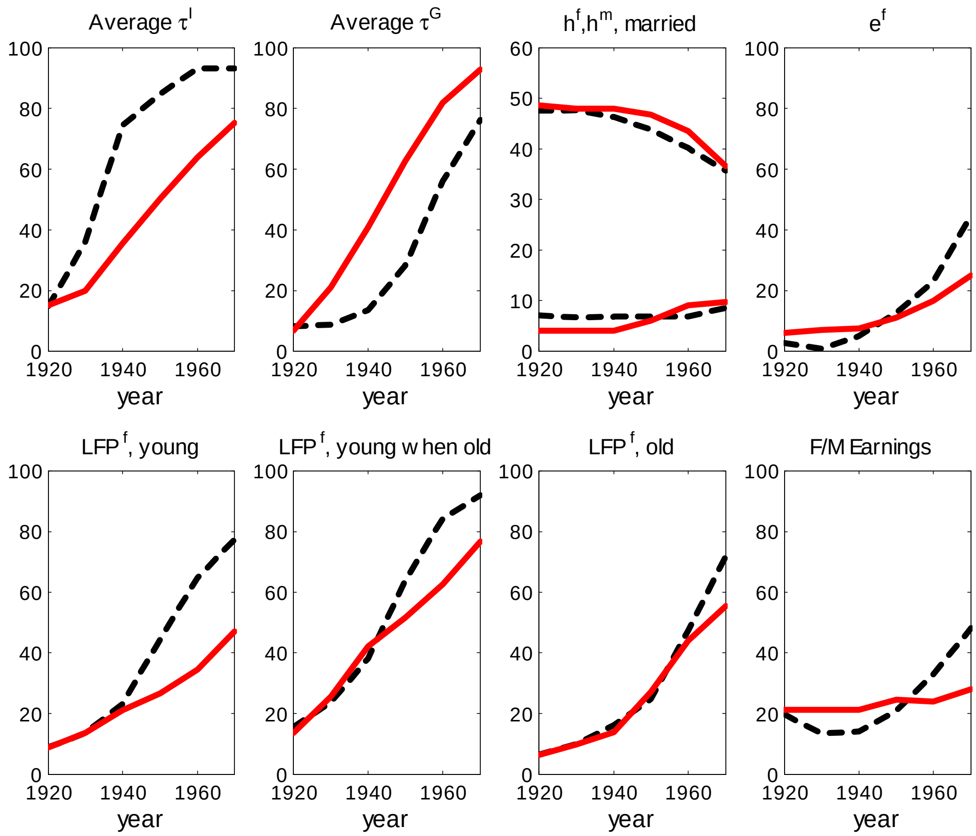


Figure 7: Model transition.

fact that the decline in q^I is very rapid between 1920 and 1950. The incentive to adopt the new I technology also varies over time as a function of fertility and the physical cost of pregnancy. While the decline in q^I is greatest between 1920 and 1950, the rise in fertility generates a significant increase in ν_I between 1930 and 1960, further spurring investment in τ^I.

The adoption of the new G technology is slightly slower than in the data. The slow adoption of the new general household technologies in the model reflects that fact that until 1940 there is no significant reduction in price, as well as the high calibrated cost of adoption of the new general household technology, which is about 3 times greater than for the new infant good technology. Households in the model substitute by increasing the adoption of new infant good technologies at a very fast rate.

The ability to invest in market skills amplifies the effect of the new home technologies on women's labor force participation and accelerates the transition in the model. We report the fraction of married women that have invested in market skills in each year in panel 4. In 1920, this fraction is equal to 3%, it then declines to 1% in 1930, reflecting the higher fertility rates at that time, and it takes off in 1940 rising to 45% in 1970. We interpret this variable broadly, reflecting not only years of formal education but also additional time invested in their careers that workers can only pursue early in their employment history. This implies that there is no single summary measure of this variable that we can use to compare the model's prediction with the data along this dimension. In figure 7, we compare women's investment in market skills in the model with the percentage of white women graduating from college by cohort[30]. The college graduation rates average 6% in 1920 and rise to 25% in 1970. Interestingly, the take off for women's college graduation rates in the data occurs in 1940, as predicted by our model.

We report the female/male ratio of average labor earnings in panel 8 (dashed line) and we compare it to the ratio of wage income for the white married population from the Census. The model predicted value of 20% for 1920 is very close the its empirical counterpart, equal to 21%. The earnings ratio drops in the model in 1930 and 1940, to 13 and 14%, respectively. This is mainly a compositional effect, due to the entry of unskilled married women in the labor force in that time period, which determines a decline of average wage income of women, conditional on participation. The earnings ratio rises steadily from 1950 onward in the model, reaching 48% in 1970, whereas in the data it is only 28% at the same date.

Labor force participation of married women increases with age in the model, consistent with the data. This can be seen from panels 5 and 6, where the dashed-dotted line corresponds to the labor force participation rate of young married women when old. The value predicted by our model is quite close to the data until 1940 after which it rises at a faster rate than in the data. This outcome is driven by the acceleration in women's investment in market skills in 1940, which is more intense in the model than in the data, as well as by the fast adoption of new infant good technologies in 1930.

The rates of participation for old married women is very close to the data. In all years, young married women (dashed line in panel 5) exhibit higher participation rates than old married women

for the new single, young married and old married agents. The population statistics on the young married and old married that we report for 1930 reflect the fact that 10/11 young marrieds in 1930 are new young marrieds and 1/11 young marrieds made their decisions in 1920 and behave accordingly. Similarly for the old married agents and for all successive years.

This treatment is consistent with the maintained assumption that at each stage in life agents make all their decision at the beginning of the period based on the current prices/wages and expected future prices.

[30]Source: U.S. Bureau of the Census, Current Population Reports, Series P-20, Educational Attainment in the United States.

(panel 7). This cohort effect, which is also present in the data, is due to the fact that old married women face lower lifetime earnings due to rising real wages and higher new home technology prices. This reduces their incentive to invest in market skills and their opportunity cost of home production relative to men.

Finally, home hours of married women decline significantly, while male home hours increase over time. The resulting distribution across spouses of home hours devoted to the production of general home goods is virtually symmetric by 1970. This outcome is mostly driven by the rising rates of women's investment in market skills at all ages, which implies a symmetric allocation of home hours between the spouses is optimal if they both participate, as well as by the rise in the participation of married women. It follows that total leisure for married men decreases substantially on average, relative to total leisure of married women who participate in the labor force. Total home and market work for participating married women, excluding the time devoted to the production of infant goods, amounts to 65 hours in 1920, and falls to 54 hours in 1970. For married men, total work amounts to 48 hours in 1920 and rises to 53 hours in 1970 in the model.

This prediction is consistent with empirical evidence for the US, on the decline in leisure time for men married to women who participate in the labor force *relative* to their wives. This phenomenon is discussed by Knowles (2005), who focusses on the period between 1965 and 2003. For our period of interest, it is not possible to measure home hours of husbands conditional on the participation status of their wife. However, the downward trend in married men's leisure relative to their wife is clearly present. Using PSID data from 1976, the average total work for married couples in which the wife participates in the labor force is 50 hours for wives and 48 hours for husbands, down from 65 and 52 hours per week, respectively, in 1920. Knowles (2005) argues that the decline in married men's relative leisure is due to an increase of wives' bargaining power within the household. In our model, this outcome stems from the fact that women's lower comparative advantage in home production when the new infant goods technology is adopted increases wives' earning potential on the labor market and induces a more equal distribution of home hours across husbands and wives in the production of general household goods.

4.3.1 Discussion

How do we interpret the fact that the model largely overpredicts the labor force participation of young married women and the rate of adoption of new infant good technologies relative to the data? The evolution of household technologies and labor productivity is the only force that influences female labor force participation and gender earnings differentials in the model, while other factors may also play a role and dampen the effect of improving technologies in practice.

One very important factor which we abstract from is the presence of "marriage bars" for women until the 1950's. Marriage bars consisted in the practice of not hiring married women or dismissing female employees when they married. Marriage bars were prevalent in teaching and clerical work, which accounted for approximately 50% of single women's employment between 1920 and 1950. Goldin (1990) extensively documents the pervasiveness of these practices for different school districts and for firms hiring office workers. The probability of not retaining 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.

Conditional on employment, differences in wages across genders are purely driven by differences in investment in market skills in our model. We do not allow for statistical or taste based discrimination. Yet, 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[31]. Albanesi and Olivetti (2006) argue that this unexplained gender earnings differential could be due to statistical discrimination. Gender discrimination would greatly reduce women's incentive to invest in market skills and participate in the labor force in our model, thus giving rise to a slower transition.

Cultural factors may also have played an important role in slowing down the increase in women's labor force participation. Fernandez and Fogli (2005) 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), 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 is still suggests a significant cultural barrier to women's employment.[32]

We also assume that the distribution of bargaining power in the household is exogenous, constant over time and equal across spouses. Empirical evidence[33] suggests that the distribution of bargaining power across spouses depends on relative wages. Based on this, the assumption that spouses have symmetric bargaining power in the 1920's seems unrealistic since married women had lower earning potential. Institutional factors, such as divorce laws, lack of political representation and marriage bars in the labor market may also have contributed to reduce women's bargaining power in the household. The gradual lifting of these constraints over the course of the twentieth century can be represented as in increase the wives' Pareto weight in the household problem in the context of our model. Knowles (2005) argues that the reduction in female/male earnings differential indeed increased the bargaining power of women and led to a decline in gender differentials in home hours. In out model, a rising Pareto weight for married women would lead to a slower increase in their participation, since this is inversely related to their Pareto weight in the household problem.

Lastly, we assume that the only cost associated to the adoption of new home technology is the monetary cost and that infant formula was readily available in all locations after its commercial introduction. In practice, there could be additional learning costs associated with the use of infant formula that slow down its diffusion in the population. Moreover, this product may not have been available in all locations. In particular, in the 1920s and early 1930s, diffusion of knowledge on infant formula mainly occurred via women giving birth in hospitals. For this period, the rate of hospital birth can in fact be considered an upper bound on the possible rate of diffusion of infant formula. The inclusion of additional adoption costs for infant formula, as well as constraints on diffusion, would dampen the adoption rate of infant formula in the model and slow down the rise in married women's labor force participation.

We plan to study the effect of endogenous distribution of bargaining power and slow diffusion of knowledge and awareness of new infant feeding technologies in future drafts.

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[31] See O'Neill (2000).

[32] Fogli and Veldkamp (2007) point to uncertainty about the effect of mother's work on the welfare of young children as an important determinant of these attitudes. They develop a model in which learning about these effects reduces uncertainty generating a rise in women's labor force participation.

[33] See Browning, Bourguignon, Chiappori, and Lechene (1994) and Mazzocco (2007).

4.4 Experiments

We now run several experiments to isolate the role of declining prices for new household and infant technology, rising real wages and exogenous changes in maternal and child mortality as well as fertility, on home hours, labor force participation and the gender earnings ratio. Our experiments are summarized in Table 7[34].

Table 7: Experiments	
Experiment 1	q^I and q^G constant
Experiment 2	q^G constant
Experiment 3	q^I constant
Experiment 4	Constant ν_I and ρ_I

We report the behavior of all variables in Table 4 and selected results from the experiments in figures 8-10.

Experiment 1 exogenously fixes the value of q^I and q^G to their value in 1920 so that the only dynamic force is the change in real wages due to increases in labor productivity. Results are displayed in figure 8. The dashed lines correspond to the transition in the full model, the dash-dotted line correspond to the transition with constant new technology prices, while the solid lines correspond to the data. There is no increase in the adoption of new infant and general household technologies over the entire period in this experiment. Changes in the labor force participation of young married women exclusively reflect changes in fertility and time cost of pregnancy. Not surprisingly, labor force participation rates for young married women decline between 1920 and 1950 due to the rise in fertility. Labor force participation of old married women does not increase between 1940 and 1970. Table 8 also shows that there is no reduction in female home hours and no increase in the investment in market skills. Hence, new home production technologies jointly play a very significant role in accounting for the rise in labor force participation of married women in the model.

Experiments 2 and 3 are designed to evaluate the role of each new home technology in isolation. In experiment 2, q^G is held constant so that there is no improvement in the general household technology. Results are displayed in figure 9. Not surprisingly, the average τ^G remains at 1920 levels for the entire time period, however, τ^I is unchanged relative to the full transition. Married women's labor force participation rises less than in the data and in the full model between 1950 and 1970, while it's virtually unaffected between 1920 and 1940. This suggests that improvements in general household play a strong role in the later time period, when there was no significant reduction in the price of new I technologies. In the early period, rising female participation rates are mostly driven by young married women entering the labor force as households adopt the new infant good technology, and this pattern is mostly unaffected by the constant value of q^G. The high value of q^G has a direct negative effect on participation of old married women. This discourages investment in market skills and indirectly also affects young married women's participation in the labor force. The fall in the labor force participation rate of young married women between 1950 and 1970, despite the high rates of adoption of new infant good technologies is due to the very low rates of investment in market skills.

[34] We do not conduct and experiment with constant real wages, since due our logarithmic specification for preferences, substitution and wealth effects associated with a generalized rise in the level of real wages exactly cancel. This implies that the transition with constant real wages is exactly the same as with rising real wages.

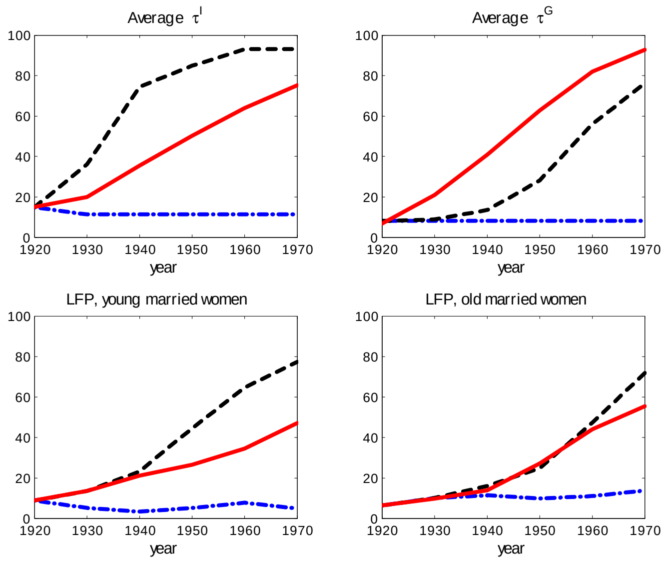

Figure 8: Transition with constant q^I and q^G.

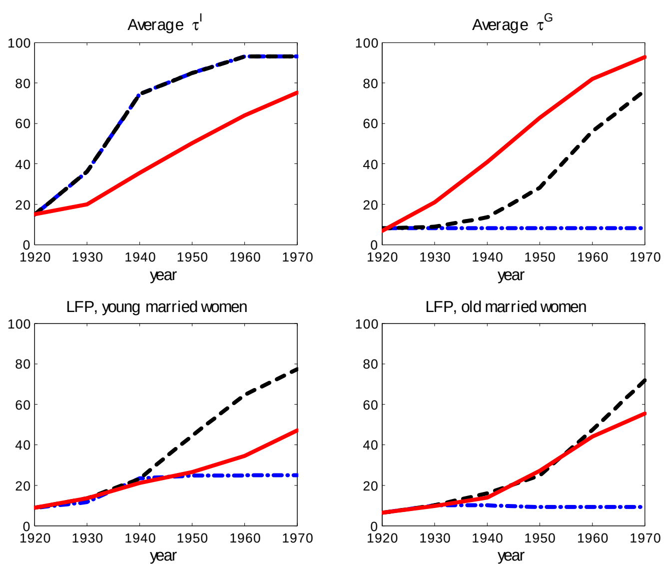

Figure 9: Transition with constant q^G.

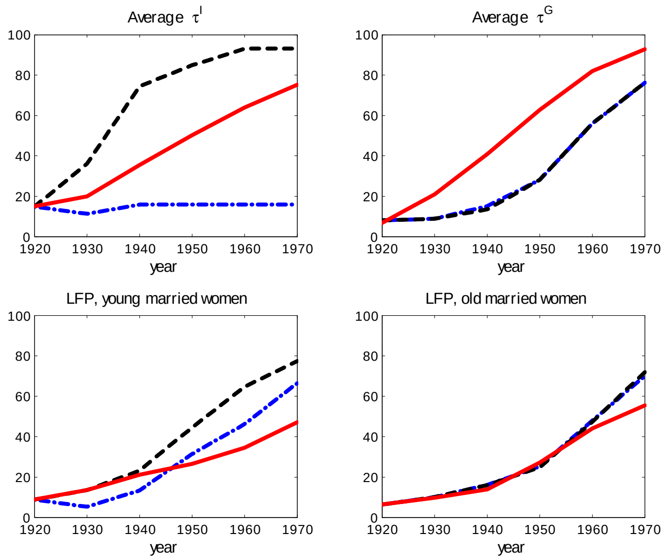

Figure 10: Transition with constant q^I.

The results for experiment 3 are displayed in figure 10. With q^I constant, the behavior of τ^I is driven exclusively by changes in demand stemming from the exogenous variation in fertility. There is a small permanent rise in τ^I between 1930 and 1940, corresponding to the sharp rise in fertility over that period. The labor force participation of young married women is lower than in the full transition and much lower than in the data between 1920 and 1950. Absent any decline in q^I, young married women's labor force participation is 9% lower in 1930, 10% lower in 1940, 14% lower in 1950, 19% lower in 1960 and 11% lower in 1970. This suggests that in the model the rise in the labor force participation of young married women is strongly driven by the decline in price of new infant good technologies. By contrast, old married women's labor force participation and the adoption of new general household technologies are virtually unaffected. Investment in market skills is lower in 1960 and 1970, which depresses the F/M earnings ratio for that period.

Results for experiment 4, in which fertility, ν_I and ρ_I are kept constant at the 1920 level are reported in Table 8. This mainly affects the participation of young married women between 1950 and 1970 when actual rates of fertility were significantly lower than in 1920. This suggests that the higher rates of fertility is not detrimental for the rise in married women's labor force participation if households can adopt the new home technologies.

Summing up, the ability to adopt *both* the new infant good technology and the new general household technology are essential for the rise in labor force participation of married women. Improvements in infant good technologies can account for a significant fraction of the rise in the participation of young married women between 1920 and 1950. Improvements in general household technologies mostly affect labor force participation of young and old married women between 1950 and 1970. There is a strong complementarity between investment in market skills and labor force participation in the old married period for women.

5 Concluding Remarks

Our results suggest that the availability of time savings technologies for the production of infant goods, such as the infant formula, is essential for the rise of participation of married women with young children between 1920 and 1950, whereas the availability of time-saving general household technologies plays a crucial role in accounting for the rise in female labor force participation between 1950 and 1970. Moreover, there is a strong complementarity in the adoption of new general household and infant good technologies, and in women's labor force participation and investment in market skills.

We concentrate on the years before 1970 since we are interested in improvements in medical technologies that occurred (and plateaued) before 1970. As discussed in the literature, after 1970 additional factors such as the availability of oral contraception and the change in divorce laws played a role in explaining the increase in women's investment in education, labor force participation and wages. Our model can easily be modified to incorporate these factors and we leave this extension for future work.

Our analysis abstracts from a potentially important force: fertility decisions. A key prediction of our model is that adoption of new infant goods technologies rises with fertility. This implies that we can account for two important facts in the U.S.: the parallel take-off in bottle feeding and fertility rates[35] in the late 1930's, and the contemporaneous rise in the fertility and labor force participation of married women with young children between 1936 and 1965. A version of our model with fertility choice has the potential to endogenously generate the contemporaneous rise in fertility and married women's labor force participation during this time period. In addition, as discussed in Section 2, in the early 1970s, there was a resurgence in breast feeding in response to new scientific discoveries regarding the positive effect of mother's milk on the immune status of the baby and on the child's resistance to infections. This development has been accompanied by a continued decline in fertility rates, accompanied by an increase in the proportion of women investing in market skills and participating in the labor force, as well as an increasing incidence and duration of breast feeding. These facts can be reconciled with our model by allowing infant formula to be less productive then mother's milk. Moreover, in a version with endogenous fertility, the immunization properties of breast milk would induce households to choose a lower *quantity* of children with higher *quality* of care provided to each offspring, thus further reducing the incentive to bottle feed. While incorporating fertility decisions is beyond the scope of the current paper, we plan to study their role in future work.

Lastly, we focus on the time-intensive nature of breast feeding. However, there is a second important aspect of this activity: breast milk must be fed at specific hours of the day, especially during the first six months of an infant's life. Hence, our estimated time cost of breast feeding likely underestimates the effective constraints imposed on mothers by this activity. The breast-pump is a relatively recent innovation that can help women overcome this inflexibility. As the new medical discoveries increasingly pointed to the importance of breast feeding for children's development, the introduction of breast pumps allowed women to reconcile breast feeding (especially during the first 3 to 6 months of their infants' life) with market work. The increase in women's labor market participation and investment in market skills that had occurred by the early 1970s likely spurred the development of the "portable" breast pump, the first model of which was marketed in 1996.[36]

[35] See Greenwood, Seshadri and Vanderbroucke (2005).

[36] Although rudimental breast pumps existed since the 16th century, the first successful mechanical pump for humans was created in 1956 by Medela, a family-owned Swiss company that still dominates the global breast-pump

References

[1] Albanesi, Stefania and Claudia Olivetti. 2006. Home Production, Market Production, and the Gender Wage Gap: Incentives and Expectations. NBER WP 12212.

[2] Apple, Rima. 1987. Mothers and Medicine: A Social History of Infant Feeding, 1890-1950. University of Wisconsin Press.

[3] Bailey, Martha J. 2006. More power to the pill: The impact of contraceptive freedom on women's lifecycle labor supply. *Quarterly Journal of Economics*, 121: 289-320.

[4] Becker, Gary S. 1985. Human Capital, Effort and the Sexual Division of Labor. *Journal of Labor Economics* 3: 33-58.

[5] Blundell, Richard, Pierre-Andre Chiappori, Costas Meghir. 2005. Collective Labor Supply with Children, *Journal of Political Economy* 113: 1277-1306.

[6] Browning, Martin, Francois Bourguignon, Pierre-Andre Chiappori, and Valery Lechene. 1994. Income and Outcomes: A Structural Model of Intrahousehold Allocation. *Journal of Political Economy* 102: 1067-1096.

[7] Bryant, W. Keith. 1996. A Comparison of the Household Work of Married Females: The Mid-1920s and the Late 1960s, *Family and Consumer Sciences Research Journal*, 24 (4): 358-384.

[8] Chiappori, Pierre-Andre. 1988. Rational Household Labor Supply. *Econometrica* 56: 63-90.

[9] Chiappori, Pierre-Andre. 1997. Introducing Household Production in Collective Models of Labor Supply. *The Journal of Political Economy* 105: 191-209.

[10] Cowan, Ruth Schwartz. 1979. From Virginia Dare to Virginia Slims: Women and Technology in American Life. *Technology and Culture* 20: 51-63.

[11] Cowan, Ruth Schwartz. 1983. More Work for Mother. New York: Basic Books.

[12] Cummins, Jason G. and Giovanni L. Violante, 2002, Investment-Specific Technical Change in the US (1947-2000): Measurement and Macroeconomic Consequences, *Review of Economic Dynamics*, 5(2): 243-284.

[13] Fernandez, Raquel and Alessandra Fogli. 2005. Culture: An Empirical Investigation of Beliefs, Work and Fertility. NBER Working Paper.

[14] Fogli, Alessandra and Laura Veldkamp. 2007. Nature or Nurture? Learning and Female Labor Force Participation. Manuscript, NYU.

[15] Fomon, Samuel J. 2001. Infant Feeding in the 20th Century: Formula and Beikost. *Journal of Nutrition*: 131: 409S-420S

market. For decades, Medela primarily sold 16-pound, industrial-grade breast pumps to hospitals for mothers whose babies were too sick to nurse. Women could also rent these pumps, or use hand-held models that made every bottle a struggle. Then, in 1996, Medela began selling light and efficient personal-use mechanical pumps that could easily be taken to the office. (see http://www.slate.com/id/2138639/#ContinueArticle).

[16] Fomon Samuel J. 1975. What are infants fed in the United States? *Pediatrics* 56: 350-355.

[17] Glick, Paul C. 1977. Updating the Life Cycle of the Family. *Journal of Marriage and the Family* 39 (1): 5-13.

[18] Goldin, Claudia. 1990. Understanding the Gender Wage Gap: An Economic History of American Women. Oxford University Press.

[19] Goldin, Claudia and Lawrence Katz. 2002. The Power of the Pill: Oral Contraceptives and Women's Career and Marriage Decisions. *Journal of Political Economy*

[20] Greenwood, Jeremy, Ananth Seshadri, and Guillaume Vandenbroucke. 2005. The Baby Boom and Baby Bust. *The American Economic Review.*

[21] Greenwood, Jeremy, Ananth Seshadri, and Mehmet Yorugoklu. 2005. Engines of Liberation. *The Review of Economic Studies* 72: 109-133.

[22] Guyer, Bernard, Mary Anne Freedman, Donna M. Strobino and Edward J. Sondik, 2000. Annual Summary of Vital Statistics: Trend in the Health of Americans During the 20th Century, *Pediatrics*, 106:1307-1317.

[23] Greenwood, Jeremy, and Nezih Guner. 2005. Marriage and Divorce since World War II: Analyzing the Role of Technological Progress on the Formation of Households. Manuscript. University of Rochester.

[24] Haines, Michael R., and Richard Sutch. 2006. Population, by marital status, sex, and race: 1880–1990. Table Aa614-683 in *Historical Statistics of the United States, Earliest Times to the Present: Millennial Edition*, edited by Susan B. Carter, Scott Sigmund Gartner, Michael R. Haines, Alan L. Olmstead, Richard Sutch, and Gavin Wright. New York: Cambridge University Press.

[25] Hanes, Christopher. 1996. Changes in the Cyclical Behavior of Real Wage Rates 1870–1990," *Journal of Economic History* 56: 856–7, December.

[26] Hauser, Robert. 1976. Fertility Tables for Birth Cohorts by Color: United States 1901-1973. Rockville, MD: National Center for Health Statistics.

[27] Hirschman, Charles and Marilyn Butler. 1981. Trends and Differentials in Breast Feeding: An Update. *Demography* 18(February):39-54.

[28] Hirschman, Charles and Gerry E. Hendershot. 1979. Trends in breast feeding among American mothers. *Vital Health Statistics* 23 3:1-46. National Center for Health Statistics.

[29] Jones, Larry E. and Michele Tertilt. 2006. An Economic History of the Relationship between Fertility and Occupation. Working Paper, University of Minnesota and Stanford University.

[30] Jones, Larry E. Rodolfo E. Manuelli and Ellen R. McGrattan. 2003. Why Are Married Women Working So Much? Federal Reserve Bank of Minneapolis Staff report 317.

[31] Knowles, John. 1999. Parental Decisions and Equilibrium Inequality. Ph.D. Dissertation. University of Rochester.

[32] Knowles, John. 2005. Why Are Married Men Working So Much? Manuscript, University of Pennsylvania.

[33] Leavitt, Judith W. 1988. Brought to Bed: Childbearing in America, 1750-1950. Oxford University Press.

[34] Margo, Robert A. 2006a Hourly and weekly earnings of production workers in manufacturing: 1909–1995. Table Ba4361-4366 in *Historical Statistics of the United States, Earliest Times to the Present: Millennial Edition*, edited by Susan B. Carter, Scott Sigmund Gartner, Michael R. Haines, Alan L. Olmstead, Richard Sutch, and Gavin Wright. New York: Cambridge University Press.

[35] Margo, Robert A. 2006b Hourly and weekly earnings of production workers in manufacturing, by sex and degree of skill: 1914–1948." Table Ba4381-4390 in *Historical Statistics of the United States, Earliest Times to the Present: Millennial Edition*, edited by Susan B. Carter, Scott Sigmund Gartner, Michael R. Haines, Alan L. Olmstead, Richard Sutch, and Gavin Wright. New York: Cambridge University Press.

[36] Martinez, Gilbert A. and John P. Nalezienski. 1979. The Recent Trend in Breastfeeding. *Pediatrics* 64: 686-692, November.

[37] Mazzocco, Maurizio. 2007. "Household Intertemporal Behavior: a Collective Characterization and a Test of Commitment," Forthcoming, *The Review of Economic Studies*.

[38] Mokyr, Joel. 2000. Why "More Work for Mother?" Knowledge and Household behavior 1870-1945. *Journal of Economic History* 60: 1-41.

[39] National Center for Health Statistics. 2000. Infant Growth Charts from the Center for Disease Control of the National Center of Health Statistics. http://www.cdc.gov/growthcharts/

[40] O'Dowd, M.J. and E.E. Philipp. 1994. The History of Obstetrics and Gynaecology. Informa Healthcare.

[41] Ramey, Valerie A. and Francis Neville. 2006. A Century of Work and Leisure. NBER Working Papers 12264, National Bureau of Economic Research, Inc.

[42] Rios-Rull, Victor. 1993. Working in the Market, Working at Home, and the Acquisition of Skills: A General equilibrium Approach. *The American Economic Review* 83: 893-907.

[43] Robinson, John P., 1985. Changes in Time Use: an Historical Overview. In Juster F. Thomas and Frank P. Stafford eds. *Time Goods and Well-Being*, Institute for Social Research, The University of Michigan.

[44] ProQuest Historical Newspapers Chicago Tribune (1849-1985), Los Angeles Times (1881-1985) and The Washington Post (1877 - 1990).

[45] Schuman, Andrew J., 2003. A Concise History of Infant Formulas (twists and turns included), *Contemporary Pedriatics*, February.

[46] Thomasson, Melissa A. and Jaret Treber. 2004. From Home to Hospital: The Evolution of Childbirth in the United States, 1927-1940. NBER Working Papers 10873.

[47] U.S. Census Bureau. 1975. Historical Statistics of the United States, Colonial Times to 1970, Bicentennial Edition.

[48] U.S. Census Bureau, Statistical Abstracts of the United States, 2003. Mini-Historical Statistics, Tables HS-13 and HS-30.

[49] Vanek, Joanna. 1973. Keeping Busy: Time Spent in Housework, United States, 1920-1970. Unpublished doctoral dissertation, University of Michigan.

6 Model Appendix

6.1 Household Problem

Given that individuals are born without any initial wealth, they will all participate in the labor force when single. Then, we can write a unified intertemporal budget constraint, valued in terms of age 1 consumption goods, given by:

$$Z_1 + \frac{Z_2}{1+R_2} \leq \left[2\xi - \sum_{j=f,m} \left(c_0^j - w_0 \xi p_0^j \right) \right] (1+R_1). \tag{18}$$

The households' unified Pareto problem is:

$$\max_{e_0^j, \tau_1^I, \left\{ c_r^j, p_r^j, \tau_r^{G(j)} \right\}_{r=0,1,2, j=f,m}} 0.5 \sum_{j=f,m} u\left(c_0^j, T - e_0^j \gamma - h_0^j \left(\tau_0^G, \tau_0^I \right) - p_0^j \bar{n} \right) + g_0 \left(G_0^j \left(\tau_0^{Gj} \right) \right)$$

$$+\beta_1 \left[\sum_{r=1,2} \beta_2^{r-1} \sum_{j=f,m} \lambda_j u\left(c_r^j, T - h_r^j \left(\tau_r^G, \tau_r^I \right) - p_r^j \bar{n} \right) + g_1 \left(G_1 \left(\tau_1^G \right), I_1 \left(\tau_1^I \right) \right) + \beta_2 g_2 \left(G_2 \left(\tau_2^G \right) \right) \right]$$

subject to (18) and (3), (1)-(2), (6), $h_2^{fI} = 0$ and $h_2^f = h_2^{fG}$. Here, the Pareto weights over age 0 utility are symmetric, consistent with the fact that agents choose the age 0 allocation individually.

Combining (9) and (13):

$$c_0^j = c_1^j \left[\beta_1 (1+R_1) \frac{\lambda^j}{0.5} \right]^{-1/\sigma}, \text{ for } j = f, m. \tag{19}$$

Similarly, combining (9) and (10):

$$c_2^j = c_1^j \left[\beta_2 (1+R_2) \right]^{1/\sigma}, \text{ for } j = f, m. \tag{20}$$

Using (9) for f and m :

$$c_1^m = c_1^f \left(\frac{\lambda_m}{\lambda_f} \right)^{1/\sigma}. \tag{21}$$

Equations (18)-(21), jointly with (9), give rise to a system of six equations in the six unknowns c_r^j for $j = f, m$ and $r = 0, 1, 2$.

6.2 Market Production and Equilibrium

The problem for the representative firm is given by:

$$\max_{d,k,c} \Xi y - wN$$

subject to (15) and (17), where w is corresponds to economy wide labor productivity in the current period. Hence, in equilibrium, w will be equal to Ξ at each date.

The resource constraint is:

$$\begin{aligned} 0 &= \sum_{r=1,2} n(r) \left(q^G \int_j \tau_r^G(j)\, d_r^{\tau_r^G(j)} dj \right) + q^I n(r) \int_j \tau_1^I(j)\, k^{\tau_1^I(j)} dj \\ &\quad + \sum_{r=1,2} n(r)\, C_r + \frac{1}{3} a_1' + \int_i \left(a_0'(i) + \xi (1+e_i)\, p(i) \right) di - Y - \sum_{r=1,2} n(r)\, a_r (1+R), \end{aligned}$$

where j indexes households in the population, $n(r)$ denotes the fraction of agents of age r in the population and:

$$\begin{aligned} C_r &= \int_i (s_r(i) + \xi(i)(1+e_i)\, p_r(i))\, di, \\ Y &= \sum_{r=0,1,2} n(r) \int_i p_r(i) * \xi(i)(1+e_i)\, di, \end{aligned}$$

where i indexes individuals in the population and capital letters denote aggregate values.

Integrating budget constraints over all households in the population:

$$A(1+R) + \int_i \xi p(i)\, di = C + q^G \int_j \tau^G(j)\, dj + q^I \int_j \tau^I(j)\, k^{I^{\tau^I}}(j)\, dj - A',$$

where i indexes all living individuals and j all living households.

Since $Y = \int p(i) * \xi(i)\, di = \int_j \tau^G(j)\, d^{\tau^G}(j)\, dj + \int_j \tau^I(j)\, k^{\tau^I}(j)\, dj + C + A' - A(1+R)$ from the resource constraint, then:

$$\int_j \tau^G(j)\, d^{\tau^G}(j)\, dj + \int_j \tau^I(j)\, k^{\tau^I}(j)\, dj = q^G \int_j \tau^G(j)\, dj + q^I \int_j \tau^I(j)(j)\, dj, \tag{22}$$

where market clearing requires $\int_j \tau^I(j)\, k^{\tau^I}(j)\, dj = K$ and $\int_j \tau^G(j)\, d^{\tau^G}(j)\, dj = D$. Then, under competitive pricing, (22) pins down the equilibrium values of q^l as a function of the technological marginal rates of transformation γ^l, for $l = G, I$.

7 Data Appendix

7.1 Demographics

Data on the total fertility rate and on the number live births are from: Hauser (1976). Data for median age at first marriage correspond to Series A 158-159 in Historical Statistics of the United States (1975). Data for median age at first birth are obtained by using information on first birth by age of mother from the National Center of Health Statistics (http://www.cdc.gov/nchs/data/statab/t991x02.pdf).

First-birth rates correspond to first live births per 1,000 women in five-year age groups ranging from 10-14 to 45-49 years old. We use Series A 119-134 in Historical Statistics of the United States (1975) in order to weight these statistics by the size of the female population in each age group. The median age at first birth in 1920 thus obtained is consistent with the statistics reported in Glick (1977, Table 1). We take the statistic for median age at last birth from this study.

7.2 Wages and Prices

7.2.1 Prices

Dollar prices are adjusted using the U.S. Bureau of Labor Statistics All Urban Consumers Consumer Price Index (CPI-U) with base 1982-1984. The index is an average of prices for all items in the CPI and across all major U.S. cities. We deflate monthly and yearly data by using the corresponding (monthly or early) CPI-U index.

7.2.2 Real Wages

The historical real wage series that is most commonly used in the literature is the series discussed in Hanes (1996). However, this series starts in 1923 and has a break during WWII (1941 to 1946). Given our focus on the 1920-1970 period, we use the wage series from Margo (2006a) as a measure of real hourly wages in manufacturing (for full-time year-round workers). This series is available for every year between 1909 and 1995. The two series move very closely although in Hanes' series the real wage is, at every point in time, bigger than in Margo's series.

7.2.3 Wage Rates by Gender

We use the series from Margo (2006b) as a measure of male and female hourly wages of production workers in manufacturing between 1920 and 1948. The data underlying our measure for wage rates were collected by the National Industrial Conference Board (hereafter, NICB) from a sample of companies representing twenty-five industries (of durable and nondurable goods) by means of a monthly mail questionnaire. Within each industry, average hourly earnings were obtained dividing the *aggregate payroll* for reporting companies by the aggregate man-hours (see Margo (2006b) for details). Unfortunately, information on hourly wages disaggregated by gender is not readily available after 1948. Hence we use data from the Handbook of Labor Statistics, 1970, Table 109 (Number and Average Straight-Time Hourly Earnings of Production Workers in Selected Manufacturing Industries, 1967-69) to compute the male and female hourly wage in 1968. Unfortunately this data is only available for selected industries. Therefore, we scale the wages upwards to match (1967-69 average of) series Ba4361 (the aggregate hourly wages based on the NICB sample). We use simple linear interpolation to fill in the missing data between 1948 and 1968.

7.2.4 Female/Male Earnings Ratios

Our series for the Female/Male earnings ratio is from Goldin (1990, Table 3.1). This is the standard series used in the literature and it provides information on the gender gap for full-time year-round workers. We also use Census data to construct a series where the gender earnings ratio is computed for the overall population. In this case we use IPUMS Census 1% samples from 1940 to 1970 (for 1970, we use the 1% State sample). Our sample includes white men and women, aged 16 through 64, living in non-farm households. We further restict the sample to observations with group quarters status equal 1, "Households under 1970 definition." We use the information on wage and salary income (INCWAGE). For all years N/A code (999999) is treaded as missing data. Since the information on income in the 1940 and 1950 Censuses is only available for sample-line persons the statistics by gender are obtained as weighted averages using sample-line weights (SLWT). For 1960 and 1970 sample-line weights coincide with person weights (PERWT).

7.3 Trends in Labor Force Participation of Married Women

7.3.1 By age and cohort

We use data from Goldin (1990, Table 2.2). These data report comparable historical information on labor force participation (LFP) rates of currently married white women from 1890 to 1980. The data are disaggregated into five age groups: 15-24, 25-34, 35-44, 45-54, 55-64. We use this data to construct labor force participation rates by cohorts. Since data are not available for 1910 we obtain the LFP by age for this decade by linear interpolation of the appropriate statistics between 1890 and 1920. In the calibration we construct LFP statistics for "young" (23 to 35) and "old" (34 to 60) married women in 1920 according to the following calculations. LFP of 'young' married women correspond to the LFP of women belonging to the 1886-1895 cohort (or, alternatively, to the LFP of 25 to 34 year old married women in 1920). The LFP of 'old' married women can be obtained in two ways. First, by averaging the LFP of married women aged 35-44, 45-54 and 55-64 in 1920 (with the appropriate population weight obtained from Haines and Sutch (2006). Second, by averaging the LFP for the 35-64 age group across three cohorts: 1856-1865, 1866-1875 and 1876-1885.

7.3.2 By number of children

We use IPUMS Census data from the 1920 through 1970 Census samples to compute labor force participation of white married women ages 16 through 64 living in non-farm households (we restict the sample to observations with group quarters status equal 1, "Households under 1970 definition.") For 1970, we use the 1% State sample.

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 time and comparability to other measures of participation.) Because employment status information is not available in 1920, we use occupation data for that year instead. 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. We report LFP by presence of children within various age categories, as well as for women with no children. These statistics are obtained by using information on the total number of children living in the household (variable NCHILD), the total number of children less than 5 years old (NCHLT5) and on the age of the youngest child (variable YNGCH). Averages are weighted using person weights (variable PERWT).

7.4 Home Hours

The statistics on home hours for married men are from Table 11.1 in Robinson (1985), they refer to a 1931-33 study. The numbers reported in Robinson (1985) show that men only spent 4 hours per week in family care activities. A reported in Vanek (1973), housewives spent 51 hours per week attending to household chores. For employed married women, defined as working for pay more than 15 hours per week, Vanek (1973, page 194) reports 26.8 hours per weeks for rural employed women and 23.6 hours per week for urban employed women. Following Ramey and Francis (2006) we take the average of these two statistics (25 hours per week). The numbers that we use for home hours are consensus estimates. Vanek (1973) reports information from a compilation of time-use studies conducted by the Bureau of Nutrition and the Bureau of Home Economics between 1924 and 1928. In all of the studies home hours by housewives range from 50 hours per week to 60 hours per week. The few studies that report home hours for men show that men spent on average between 3 and 5 hours per week in home activities. See also Ramey and Francis (2006) and Bryant (1996).

7.5 Physical and monetary cost of exclusively breast-feeding an infant

We base our estimates of the total time and monetary cost of exclusively breat-feeding an infant by using information from the National Association of Pediatrics, Pediatric Advisor (2005) (http://www.med.umich.edu/1libr/pa/pa_formula_hhg.htm). According to this source, the number of feedings per day varies by the infant's age. That is, an infant should be fed 6 to 8 formula feedings per day for the first month, 5 to 6 formula feedings per day from 1 to 3 months, 4 to 5 formula feedings per day from 3 to 7 months, 3 to 4 formula feedings per day from 7 to 12 months. The number of feedings decreases with the age of the child as solid food is introduced in the later period.

7.5.1 Physical cost

It is reasonable to think that the time spent for each feeding (time for the actual feeding and cleaning up) ranges from 20 to 30 minutes. Combining this information with the number of daily feedings by age of the infant we can obtain rough estimates of the weekly time cost of feeding an infant (on average) during his/her first year of life. We find that on average a mother would spend 700 to 900 hours breast feeding a baby during his first 12 months of life. This calculation implies that she would spend on average 13.6 to 17.3 hours per week breast-feeding the infant. These are the numbers reported in Section 2.

7.5.2 Monetary cost

In order to compute this cost we start by using the information from the National Association of Pediatrics. According to this source, the amount of formula needed for a baby varies by the infant's weight. Newborns usually start with 1 ounce per feeding, but by 7 days they can take 3 ounces. The amount of formula that most babies take per feeding (in ounces) can be calculated by dividing the baby's weight (in pounds) in half. We use this information as well as the 2000 Infant Growth Charts from the Center for Disease Control of the National Center of Health Statistics (available at: http://www.cdc.gov/growthcharts/) to obtain the estimates of the average daily intake of infant formula (in liquid ounces) for a baby of median weight for the first month, months 1 to 3, 3 to 7 and 7 to 12 of his life. Given our estimates of the price per 'ready-to-feed' liquid ounce of Similac we can obtain the average daily cost of exclusively breast-feeding an infant with Similac that we report in Section 2.3. We use the 2000 CDC infant growth chart because it can be used to assess the growth of exclusively breast-fed infants, a reasonable assumption for the mid 1930s. This is because the mode of infant feeding influences the pattern of infant growth. In general, exclusively breast-fed infants tend to gain weight more rapidly in the first 2 to 3 months. From 6 to 12 months breast-fed infants tend to weight less than formula-fed infants. The 2000 CDC Growth Chart reference population includes data for both formula-fed and breast-fed infants, proportional to the distribution of breast- and formula-fed infants in the population. Also available are the 1977 growth charts for babies under 2 years old, which are still used by many doctors. The 1977 growth charts are based on a study conducted in Ohio from 1929 to 1975. The babies in this study were primarily fed formula or a combination of breastmilk and formula and often started solids before 4 months. As a result, the 1977 growth charts are not a reliable indicator of the growth of children who are mostly breast-fed and delay solids until around six months, as it was the case in the 1930s.

7.6 Infant Formula

The table below reports differences in the composition of different types of milk and of first and second generation infant formulas. Data on nutritional content of human and cow milk and of the earlier formulas are from Packard and Vernal (1982, page 140). Data for Nestle are from Apple (1987). Data on the more contemporary formula are from Hambraeus (1977). The percentage value refer to grams of fat\proteins\carbohydrates per 1,000 grams or per 5 liquid ounces of milk/formula. We use data on the composition of SMA for the 1920s since we could not find information for Similac. However, as shown in the last two columns, in 1977 the nutritional content of the two types of formulas is basically identical. We assume that this was also the case in the early 1920s. The information on the label of a can of Similac Advance currently sold in stores show that its composition is identical to the one of its 1977 version. Note that in the 1970s nutritional scientists realized that it was wrong to design the formula to exactly match human milk. Current FDA regulation prescribes that the protein content of infant formula should range between a minimum of 1.2% and a maximum of 3%. The fat content should range between 2.2% and 3.9%.

Table A1: Percentage Composition of Human Milk, Cow's Milk, Cow's Milk Modifiers and 'Humanized' Formula

	Human Milk	Cow's Milk	Nestle 1929	SMA 1920s	SMA 1977	Similac\Enfamil 1977
Proteins	0.9%	3.4%	2.3%	0.9%	1.5%	1.5%
Fat	4.4%	3.6%	2.3%	4.6%	3.5%	3.6%
Carbs	6.6%	4.8%	5.7%	6.5%	7%	6.8%

7.6.1 Humanized Infant Formula: Similac

The infant formula that became known as Similac was developed in the early 1920s by two Boston based scientists, Alfred W. Bosworth, a milk chemist working for the biochemistry department of Harvard Medical School, and Henry Bodwidtch, a Boston pediatrician, who was employed at the Boston Floating Hospital. During their studies Bosworth and Bodwidtch tested more than 200 formulas in clinical trials before they considered their infant formula complete (see Schuman, 2003). In 1924 they agreed to have the formula marketed by the Moores and Ross Milk Company. Initially, the formual was sold only through physicians, who would place their own label on the plain cans. In 1926, this formula was commercialized under the name Similac.

As discussed in Section 2, we measure technological progress embedded in infant formula based on a time series for the real price of Similac constructed from historical ads from the Chicago Tribune, the Los Angeles Times and the Washington Post. For each year between the mid 1930s and the mid 1980s we have monthly information on price, quantity and type (powder, concentrated liquid, ready-to-feed) of Similac items on sale in drugstore chains in these three cities. Figure 11 shows monthly data for the price of one ready to feed liquid ounce of Similac disaggregated by city (the procedure to obtain this unit price is explained below). Interestingly, there is very little variation in the (discounted) price of Similac across the different cities before 1970. Hence, in Section 2 we present yearly data computed by averaging prices across the three cities. The Figure also shows that we do not have information for each month/year. If the information for one year is missing we interpolate prices across the two adjacent years. 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. Hence, for some of the early years our series is based on the price of Similac for the Chicago area. 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 time series of prices. However, it is interesting to note that in the ads the 16 ounces can of powder Similac was often referred to as the \$1.25 worth Similac and not by the weight of the can's content. This seems to suggest that the regular price of the 'regular' can of powder Similac 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 can of Similac at discount prices. Hence, we conclude that the actual 'regular' price of the 16 ounces can of Similac was probably much lower and closer to the discounted price in the early 1950s than it was in the mid 1930s.

The data that we use in our analysis are an average of the price of powder and concentrated liquid. These two types of Similac did not differ in terms of their chemical composition. The only differences among the two types of formula were (and still are) in the proportions of water that needs to be added in order to obtain one ready-to-feed liquid ounce of infant formula and in the differential amount of time required to effectively mix powder or concentrated liquid with water. Hence, the difference in the quality of the two types of products seems to be quite negligible. In order to average the prices of the two types of product, we compute the price of one ready-to-feed liquid ounce of formula for each of the two product types. We use the following conversion rules. According to the instructions reported on the current Similac labels, 25.6 ounces of powder can make approximately 196 fluid ounces of formula whereas 13 ounces of concentrated liquid Similac can make 26 fluid ounces of formula. In order to obtain the price of one unit (i.e. one liquid ounce) of formula in real terms we simply divide the (real) price of the can by the quantity of formula (in liquid ounces) that can be obtained by using the content of the can.

Over time the nutritional content of Similac improved with the introduction of iron-fortified formulas in 1959. Since we are using prices of items on sales we actually have very few price observations for the iron-fortified Similac. We have excluded them from the current analysis in order to reduce the quality-bias in our series. Similarly for the ready-to-feed version of the product that became available in the 1970s.

We have also collected data for Enfamil, another humanized formula that became available in the late 1950s/early 1960s. However, data on Enfamil are only available since 1961 and only for very few years. Adding the price for Enfamil to our data does not change the time series for

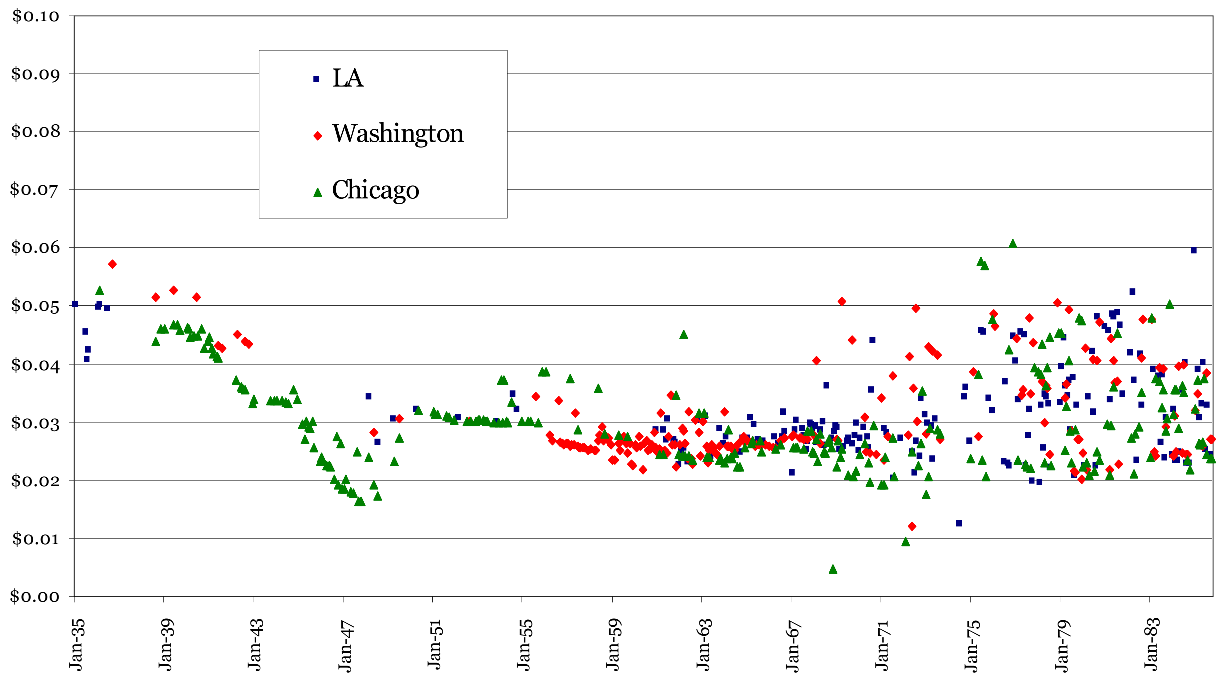

Figure 11: Average Monthly Price of Similac

the price of infant formulas hence we have excluded the price observation for Enfamil from our analysis.

7.6.2 Milk Modifiers: Nestle's and Mellin's

We have also extended the price series backward by collecting the prices of the first-generation of milk-based formulas (Mellin's and Nestle's) that were commercially introduced in the late 19th century. These formulas were milk modifiers, that is, they were mixed in given proportions to cow milk in order to obtain the actual formula to be fed to the baby. Data, once again, are from ads from the Chicago Tribune, the Los Angeles Times and the Washington Post for the period. The information collected from the ads, however, did not include quantities only prices. We obtain estimates for the quantities by using a variety of sources including some figures from Apple (1987) and historical ads, labels and bottles sold on Ebay, etc.[37]. Below we report how the sizes of Mellin's and Nestle's (both available in different sizes) were computed. Also, for both products the powdered formula had to be mixed with milk (and water) in given proportions. Hence, in order to compute the price of Mellin's and Nestle's per liquid ounce of 'ready-to-feed' formula we had to also obtain the price series for cow milk (we do not have this problem with Similac and Enfamil because they only required water). For milk we use the series of retail price of "delivered" fluid mik (series 195 from the Statistical Abstract of the United States: Bicentennial Edition). The price reported in this series is an order of magnitude higher than the one reported in the wholesale price series from the NBER. Howevever, the retail price is reasonable when compared with a more recent series on retail price of milk sold in stores (and not 'delivered' milk) available from the University of Wisconsin Dairy Marketing and Risk Management Program (http://future.aae.wisc.edu/data/monthly_values/by_area/307?tab=prices&grid=true) for the period 1980-1997. Below we report the calculations that we used to obtain the price of one liquid ounce of 'ready to feed' formula.

Nestle's Sizes

Nestle's infant food came in different sizes:

1. The size sold at $0.5 at regular price would correspond to 1lb of powder formula. We find this information from historical ads that we found on ebay.
2. The "hospital size" can of powder Nestle's weighted 4.5lb. This information is reported in Figure 3.3, Apple (1987).
3. There seem to be also additional, unknown, sizes of the Nestle's cans. Since we do not have this information we drop this price observations from our sample.

Size and type may have changed in the 1920s. Therefore, non-hospital size packages sold at a regular price of more than $0.5 (essentially all non-hospital packages after about 1919) are excluded from the series.

Conversion factor

We use the following calculations in order to obtain the price of one liquid ounce of 'ready to feed' formula: 6 table spoons + 20 oz of cow's milk + 15 oz water = 38oz of liquid (where 2

[37] See for example: http://americanhistory.si.edu/collections/object.cfm?key=35&objkey=110 and http://cgi.ebay.com/MELLINS-INFANT-FOOD-MELLINS-FREE-SAMPLE-AND-LARGE_W0QQitemZ140042472041QQihZ004QQcategoryZ893QQssPageNameZWDVWQQrdZ1QQcmdZViewItem

table spoons are equal to 1 liquid oz). This information is taken from page 12 in the August 1929 issue of the Journal of the American Economic Association. The calculation above assumes that 1 table spoon of powder is equal to 9 gr of powder, based on current package descriptions (where, generally, 1 scoop = 9 gr, approximately). The conversion factor that we use to go from table spoons to liquid oz is as follows: 1oz = 28.3495231 grams = 3.149947011 tbsp = 0.524991169 servings of 6 tbsp.

Mellin's Sizes

There were only two sizes of Mellin's – small and large bottles. The large bottle had a net weight of 10oz (Figure 5.6, Apple (1987)), an approximate volume of 16oz (authors communication with ebay seller), and approximate dimension of 6" to 6 $\frac{3}{4}$" height and 3" diameter. The small bottle's approximate dimensions are 5 $\frac{1}{2}$" height and 2 $\frac{1}{2}$" diameter (authors communication with ebay seller). Based on dimensions, we can estimate that the small bottle should contain 60% to 64% as much formula as the large bottle. If we use 60%, it's net weight is 6oz and it's volume is 9.6oz.

Type

Data for Mellin's do not report whether the product was sold in powdered or liquid form. The mixing directions for Mellin's formula call for use of "level tablespoons." Combined with information on types of formula generally available in the relevant time period, we assume that Mellin sold only powder formula.

Conversion factor

We use the following calculations in order to obtain the price of 1 liquid oz of 'ready to feed' formula (assuming that the large size corresponds to a 16oz bottle and the small one corresponds to a 9.6oz bottle): 6tbsp + 16oz cow's milk + 12oz water = 31oz of liquid. This information is taken from Figure 5.4 in Apple (1987). Since 6tbsp = 3 oz, by volume this implies that 1oz of powder = 31/3 liquid oz of usable ready to use formula.

7.6.3 Additional information on changes in breast-feeding patterns

Table A2 reports the statistics on breast feeding rates by child's year of birth and by duration from Hirschman and Hendershot (1979). Entries represent the percent of ever-married 15-44 year old women who breast fed their first or second child by duration of breast feeding and year of birth of child. The table shows a decline in breast-feeding from over 70 percent of first-born babies in the 1930s, to slightly below 30% in the early 1970s. A comparable downward trend is also evident for second born babies, with mothers being less likely to breast feed their second child than their first child. This differential is common across all cohorts of babies, except for the 1930s. For the most recent cohort only 23% of second born babies were breast fed, down from 29% for first born babies. Starting with the 1951-1955 cohort, data are also available for two categories of duration of breast feeding, less than three months and more than three months. Once again the data show a steeper decline in the fraction of women who breast fed at longer duration. Approximately 18% of mothers breast fed their first born babies for 3 months or more in 1951-1955. By the cohort of babies born in 1971-1973 only 7% of mothers breast fed their first child for three months or more. These studies also present interesting evidence on how breast feeding rates vary with indicators of social status over this period. They show that, for all cohorts, college educated women are more likely to breast-feed than women with lower levels of educational attainment. However, statistically significant differentials in breast feeding incidence by education do not extend to the duration of breast-feeding. In additiona, professional women, women living in the Western regions of the United states and white women were also more likely to breast feed during this period. A similar pattern is still observed today.

It is also interesting to see how the relation between the incidence of breast-feeding and education changes over time. For births occurring in 1950 or earlier, the variation in breast-feeding rates by education was small. In the late 1950s, a U-shape relationship emerged, with breast feeding more likely among women with the least or most years of education. By the 1970s, breast feeding was least common among women with the lowest levels of education, a pattern that persists to the year 2000.

Table A2: Percentage of breast fed infants by year and order of birth

Year of birth	1931-1935	1951-55	1961-65	1971-73
		First child		
all durations	72	49.8	37.5	29
<3 months		31.7	25.2	22
$\geq$ 3 months		18	12.3	7.1
		Second child		
all durations	76	34	24.7	23.5
<3 months		20	15.4	16.4
$\geq$ 3 months		14.5	9.3	7.1

Source: Table A and Table B in Hirschman and Hendershot (1979). The data for 1931-35 are based on the 1965 National Fertility Study. For the remaining cohorts the analysis data are based on the 1973 National Survey of Family Growth. The first child sample includes all women with 1 or more live births whose first baby lived with them for at least 2 months. For second births the sample includes all women with 2 or more live births whose second baby lived with them for at least 2 months.

The data used to document changes in breast feeding practices are based on retrospective surveys. This might pose problems related to the precision of the information especially for older cohorts of women. Moreover, more recent cohorts of women are less likely to have completed their fertility. However, the numbers that we report are consistent with evidence from hospital discharge records and, at least to our knowledge, represents the most accurate description of trends in breast feeding over this period. The sporadic evidence from alternative records (hospital discharge records and the Ross Mother's survery discussed in Section 1.2) is not extensive but it consistently shows that by the early 1970s less than 25% of newborn babies were breast fed at hospital discharge or at 1 week. According to all records, the early 1970s are characterized by the lowest incidence of breast-feeding of the entire 20th century. Since then new medical findings on the potential immunization properties of breast-feeding, breast feeding rates have increased steadily. In year 2003 approximately 71% of mothers breast fed at birth and 62.5% exclusively breast fed their baby at 1 week. These breast feeding rates are comparable to the ones observed in the 1930s.

7.7 Household Appliances

We use Gordon's quality-adjusted Divisia price index for household appliances (Gordon, 1990) rescaled by real wages as a measure of the time price of new general household technologies. This price series is available from 1947 to 1984. In order to obtain a series starting in 1920 we extrapolate the quality-adjusted price index backward by applying to home durables the procedure developed by Cummins and Violante (2002) to construct a quality-adjusted post-1984 price index for the capital goods that make up equipment and software. Their procedure is based on the assumption that the speed of technological change for capital goods in equipment and software can be measured as the difference between the growth rate of constant-quality consumption and the growth rate of the good's quality-adjusted price index. Since NIPA data on household durables are not disaggregated by type of appliance we cannot perform the full-fledged adjustment proposed in Violante and Cummins but simply apply the relevant part of their procedure to our aggregate series for household appliances.

In our application we use Gordon's Divisia price index for eight household appliances and the NIPA price index for kitchen and other household appliances (NIPA Table 2.5.4, row 30). Both series are available for the period 1947-1984. Following Cummins and Violante we use the pairs of price indexes over the entire period to estimate an econometric model of Gordon's quality adjusted price index (in logs) as function of a time trend, the current value of the NIPA price index (in logs) and the growth rate of lagged GDP (from NIPA). The estimated quality bias implicit in the NIPA series is the coefficient on the NIPA log price. We then extrapolate the Gordon's quality-adjusted price index backward by using the NIPA price series for the pre-1947 period and our estimate of the quality bias. In our exercise we use the Gordon's quality-adjusted price index that does not include further 'adjustments' for energy efficiency or repair costs since these changes occurred post 1970.

We estimate a quality-adjustment of -3.04% per year between the two series over the 1947-1984 period. The first available year for the NIPA series is 1929. The NIPA price index for kitchen and household appliances increased by 0.98% per year between 1929 and 1947. By combining this information with the estimated quality adjustment we obtain an (estimated) exponential decline in the quality-adjusted price index for household durables of 2.06% (0.98%-3.04%) per year between 1947 and 1929. Since we need to obtain a price series starting in 1920 we extrapolate this adjusted price index backward by assuming that the rate of NIPA price change between 1920 and 1929 is the same as the one observed between 1929 and 1947.

Table 8: Transition and experiments

	LFP of Young Married Women						LFP of Young Married Women when "Old"					
year	Data	Model	Experiment 1	Experiment 2	Experiment 3	Experiment 4	Data	Model	Experiment 1	Experiment 2	Experiment 3	Experiment 4
1920	9%	9%	9%	9%	9%	9%	14%	16%	16%	16%	16%	16%
1930	14%	14%	5%	12%	5%	12%	26%	24%	15%	12%	24%	25%
1940	21%	23%	3%	24%	13%	24%	42%	38%	12%	12%	39%	38%
1950	27%	45%	5%	25%	31%	43%	52%	64%	15%	11%	65%	63%
1960	34%	65%	8%	25%	46%	63%	63%	84%	19%	11%	82%	84%
1970	47%	77%	5%	25%	66%	76%	77%	92%	16%	11%	92%	92%
	LFP of Old Married Women						Women's Investment in Market Skills					
year	Data	Model	Experiment 1	Experiment 2	Experiment 3	Experiment 4	Data	Model	Experiment 1	Experiment 2	Experiment 3	Experiment 4
1920	6%	7%	7%	7%	7%	7%	6	3%	3%	3%	3%	3%
1930	10%	10%	10%	10%	10%	10%	7	1%	1%	0%	1%	3%
1940	14%	16%	12%	10%	16%	17%	8	5%	0%	0%	7%	5%
1950	27%	25%	10%	9%	25%	25%	11	13%	3%	0%	14%	10%
1960	44%	47%	11%	9%	48%	47%	17	23%	5%	0%	19%	23%
1970	55%	72%	14%	9%	70%	73%	25	45%	1%	0%	38%	52%
	Adoption of new infant good technology						Adoption of new general household technology					
year	Data	Model	Experiment 1	Experiment 2	Experiment 3	Experiment 4	Data	Model	Experiment 1	Experiment 2	Experiment 3	Experiment 4
1920	15	15%	15%	15%	15%	15%	7	8%	8%	8%	8%	8%
1930	20	36%	11%	36%	11%	36%	21	9%	8%	8%	9%	9%
1940	36	74%	11%	74%	16%	74%	41	13%	8%	8%	15%	13%
1950	50	85%	11%	85%	16%	85%	63	28%	8%	8%	28%	28%
1960	64	93%	11%	93%	16%	93%	82	56%	8%	8%	56%	56%
1970	75	93%	11%	93%	16%	93%	93	76%	8%	8%	76%	76%
	Married Women's Home Hours						Men's Home Hours					
year	Data	Model	Experiment 1	Experiment 2	Experiment 3	Experiment 4	Data	Model	Experiment 1	Experiment 2	Experiment 3	Experiment 4
1920	49	48	48	48	48	48	4	7	7	7	7	7
1930	48	49	49	49	49	48	4	7	7	7	7	7
1940	48	48	49	49	45	47	4	7	7	7	7	7
1950	47	43	48	48	43	43	6	7	7	6	7	7
1960	44	37	47	48	39	37	9	7	7	6	7	7
1970	37	28	49	49	31	27	10	9	7	7	9	9
	F/M Earnings											
year	Data	Model	Experiment 1	Experiment 2	Experiment 3	Experiment 4						
1920	0.21	0.20	0.20	0.20	0.20	0.20						
1930	0.21	0.13	0.16	0.12	0.16	0.16						
1940	0.21	0.14	0.11	0.11	0.32	0.15						
1950	0.25	0.21	0.18	0.10	0.30	0.20						
1960	0.24	0.33	0.26	0.10	0.32	0.32						
1970	0.28	0.48	0.17	0.10	0.46	0.49						