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Maternal Health and Fertility: An International Perspective

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Maternal Health and Fertility: An international perspective*

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This paper examines the impact of the decline in maternal mortality on fertility and women's human capital. Fertility theory suggests that a permanent decline in maternal mortality initially increases fertility and generates a permanent rise in women's human capital, relative to men. The resulting rise in the opportunity cost of children leads to a subsequent decline in desired fertility, generating a boom-bust response. We assess these predictions using newly digitized data on maternal mortality for 25 advanced and emerging economies for the time period 1900-2000. The empirical estimates suggest that the decline in maternal mortality contributed significantly to the baby booms and subsequent baby busts experienced by these economies in the twentieth century, and that the female-male differential in education attainment grew more in those countries that experience a sizable maternal mortality decline.

1 Introduction

The improvements in health and associated reductions in mortality starting in the 1850s have been linked to the secular decline in fertility, the rise in human capital and the growth in output and living standards that have taken place in advanced economies in the last 150 years. Remarkably, this vast literature has completely ignored the impact of medical progress on women. In the U.S., one mother died for every 118 live births in 1900, and maternal

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mortality accounted for over 15% of all deaths of women 15-44 between 1900 and 1930, the second largest cause of death after tuberculosis. Health risks in connection to pregnancy and childbirth were severe in most advanced economies up until the 1930s. Advances in general medicine, such as the development of bacteriology, the introduction of sulfominydes and antibiotics, the diffusion of blood banks, and in the improvement in obstetric practices led to a sharp reduction in maternal mortality between 1930 and 1960 in advanced economies, as shown in figure 1. The virtual elimination of maternal mortality risk by the early 1960s was accompanied by a similar reduction in the incidence of pregnancy-related conditions.[1]

This paper examines the impact of the decline in maternal mortality on fertility and women's human capital. To guide the analysis, we develop a model of fertility choice with endogenous human capital that incorporates both maternal and infant mortality. An improvement in maternal health decreases the health costs of pregnancy and lengthens women's productive lifespans, increasing the return to their human capital. A permanent decline in maternal mortality initially increases fertility and generates a permanent rise in women's human capital, if initial fertility and initial infant mortality are sufficiently low. The resulting rise in the opportunity cost of children leads to a subsequent decline in desired fertility, generating a boom-bust response. The size of the initial boom is positively related to the magnitude of the decline in maternal mortality, while the size of the bust rises with the returns to human capital. These results suggest a new mechanism through which mortality reduction can influence fertility and human capital. We assess the theoretical predictions empirically, using newly digitized data on maternal mortality based on original national sources, for 20 advanced economies from 1900 onward, with data for Sweden starting in 1800, and for Argentina, Chile, Mexico and Peru starting in the mid 1930s. Using these new data, in addition to existing data on fertility, infant mortality, and a number of health and economic indicators, we also conduct a comprehensive analysis of other drivers of fertility during the twentieth century, such as the decline in infant mortalities, the rise in wages and output, the transition from agriculture to industry, and the role of World War II. We also examine the impact of the maternal mortality reduction on the female-male differential in

[1]Pregnancy-related morbidity also took a severe toll on women's health. A variety of conditions, such as puerperal fever, obstetric fistulas, hypertensive disorders, and chronic anaemia, could lead to protracted or permanent disability. Historical data on pregnancy-related morbidity is only available for the United Kingdom (Loudon, 1992), and there are no systematic time series data on the evolution of maternal morbidity. Based on post-partum readmission data, 12% of all live births generated some form of maternal morbidity in the late 1920s (Kerr, 1933). Albanesi and Olivetti (2010) report that post-partum pregnancy-related conditions requiring hospitalization dropped by 93% between the late 1920s and the mid 1980s in the U.S., a magnitude similar to the drop in maternal mortality over the same period (1930-1987). Throughoout the analysis, we will maintain that the decline in maternal mortality is accompanied by a similar reduction in pregnancy-related morbidity. This assumption is standard in the literature on the economic impact of disease eradication.

education a attainment.

Our findings suggest that the decline in maternal mortality contributed significantly to the baby booms and subsequent baby busts experienced by advanced economies in the twentieth century, providing a novel, integrated explanation for these important demographic phenomena. Baby booms occurred only in countries that experienced a large decline in maternal mortality and that had initially low fertility and infant mortality, confirming a key prediction of the theory. Total fertility rates started to rise 10 years after the start of the maternal mortality decline, peaked between 20 and 25 years, and began to decline after 20 to 35 years. Fertility at peak rose between 10 and 40% percent. Baby busts were more pronounced in countries with high income per capita, high proportion of industry and high levels of secondary education. This suggests that high returns to human capital were positively linked to the baby busts. The decline in infant mortality was an important determinant for the negative trend in fertility for all the countries in the sample. Finally, we show that the female-male differential in educational attainment grew more in those countries that experience a large decline in maternal mortality, broadly confirming the predictions of the theory.

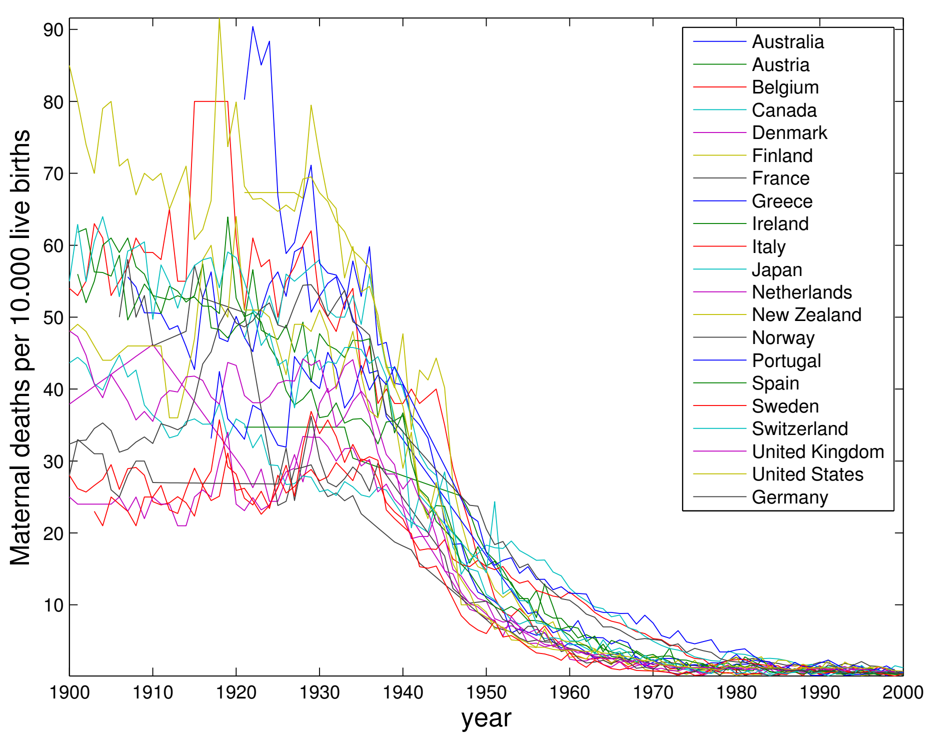


FIGURE 1: Maternal Mortality in Advanced Economies

Sources: MMR (maternal deaths per 100,000 live births) from Loudon (1992), UN Demographic Yearbook (Various issues), Meigs (1917), national sources compiled by the author.

This paper's main contribution is to the macroeconomic literature on the link between mortality, fertility and human capital. Following the pioneering work of Preston (1976), the demographic literature has concentrated on the impact of the reduction in youth mortality on the secular decline in fertility (Preston 1978, Haines and Preston 1991, and Haines 1997), while the economic literature has emphasized the link between mortality reduction and the increase in the returns to human capital (Becker and Barro, 1988, Becker, Murphy and Tamura, 1990, Soares 2005). The twentieth century baby booms and busts and the faster growth in women's human capital relative to men in advanced economies have been left unexplained. This paper shows that the decline in maternal mortality can account for both these phenomena, using evidence from a broad spectrum of countries.

The paper also makes a contribution to the economic literature on baby booms. Despite the remarkable magnitude of the baby booms experienced by many advanced economies in the twentieth century, their origins are still poorly understood. A popular view is that baby booms are a post World War II phenomenon, with the economic recovery from the war triggering a rise in fertility. Doepke, Hazan and Maoz (2007) also attribute the U.S. baby boom to World War II, though they rely on a different mechanism. They argue that the rise in labor force participation of married women during the war crowded out younger women after the war, causing them to opt for marriage and childbearing. Extending this reasoning, they conclude that baby booms were more likely to occur in countries who participated in World War II.

We show that fertility began to rise *before* or during the war in all countries that experience a baby boom, though births declined in some countries between 1943 and 1945. Moreover, the occurrence of a baby boom is not related to participation in the war, and that both neutral and non neutral countries experience baby booms after a sharp decline in maternal mortality. The fact that pre-war maternal mortality was considerably higher in non-neutral countries may account for the fact that these countries experienced large booms. Amongst non-neutral countries, we find that the number of casualties as a fraction of the population was a critical factor, with fertility responding strongly to a decline in maternal mortality in countries with a low number of casualties, and a much smaller response for countries with a high number of casualties. Countries with a higher number of casualties also experienced a greater degree of war-time destruction, resulting a greater rise in income after the war. The smaller growth in fertility in these economies is inconsistent with the hypothesis that fertility is positively linked to relative income.

Perhaps the best known explanation of the U.S. baby boom is Easterlin's (1961) "relative income" hypothesis, based on the notion that desired fertility would be high for generations whose income is higher than their parents. According to this view, the recovery from the Great Depression and and the post-war economic booms expereinced by many countries should be associated by a rise in fertility. Jones and Schoonbroodt (2010) also argue that fertility should be procyclical, as rise in the number of children can serve as a mechanism to smooth consumption across generations, and they argue that this observation can explain the cross-country variation in fertility during the twentieth century. To explore the role of relative income, we examine the behavior of fertility in countries with different initial economic conditions. We find that countries with small values of the change in actual and detrended GDP before the baby boom exhibit a larger rise in fertility in response to a maternal mortality decline, which is inconsistent with the relative income hypothesis, though it can be explained by the fact that these countries display high initial maternal mortality.

Greenwood, Seshadri and Vanderbroucke (2005) propose that the diffusion of home appliances was a key determinant of the baby boom in the U.S., as it reduced the time cost of children. On this basis, they also argue that other high income economies with high rates of urbanization/industrialization should have also experienced a baby boom, as home appliances were more likely to be available in these countries. Our analysis shows that the high income countries are the ones that display the highest levels of initial maternal mortality and the lowest levels of initial fertility, and these factors can account for the timing and the size of the baby booms and busts they experience. By contrast the timing of the diffusion of home appliances differs widely across countries, leaving open the possibility that the rise in fertility and the resulting increase in the number of children per household, a key determinant of the demand for home hours (Ramey, 2008), may have influenced the demand for home appliances.

This paper is related to Albanesi and Olivetti (2010), who show that the decline in maternal mortality is associated with a boom-bust response in fertility and a permanent rise in women's human capital relative to men in the U.S., exploiting the cross-state variation in initial maternal mortality. Jayachandran and Lleras-Muney (2009) study of the impact of maternal mortality decline on female literacy in Sri Lanka. Their estimates suggest a strong positive effect, which they interpret as consistent with a rise in parental investments in the education of daughters.

The paper is organized as follows. Section 2 describes the theoretical model that underpins the empirical analysis. Section 3 examines the empirical evidence on the link between maternal mortality reduction and fertility in a sample of 25 advanced and emerging economies for the time period 1900-2000, and for Sweden starting in 1800. Section 4 examines the link between maternal mortality and fertility in a sample of emerging economies in the post-war period. Section 5 concludes.

2 Theory

We now examine a model of fertility choice and human capital investment that explicitly incorporates maternal mortality. The model predicts that a decline in maternal mortality is associated with a temporary rise in fertility and a permanent rise in women's human capital. These predictions will provide a conceptual framework for the empirical analysis.

The model is inhabited only by women, that is, all adults are female and all offspring are female. This framework, though clearly not realistic, captures the essential forces shaping fertility decisions, and the incentives to invest in daughters' human capital. Albanesi and Olivetti (2010) analyze a general version of the model, with agents of both genders, delivering similar results.

Adult women are endowed with a given level of human capital and live for one period. They derive utility from their own consumption and, as in Becker and Barro (1988), from the quantity and quality of their daughters, the latter depending on the daughters' human capital. Mothers choose the number of births and their daughters' human capital. Mothers may die in childbirth. The maternal mortality risk is a function of the maternal mortality rate, which they take as given, and of the number of births.

Mothers and daughters face the same decision problem, given their endowment of human capital, though they may experience different maternal mortality. Mothers have perfect foresight on the value of all exogenous variables entering their daughters' problem, and they take as given their daughters' decisions. Thus, women's decision problem can be formulated recursively with human capital serving as a state variable.

The decision problem is represented by the following Bellman equation:

$$U(e;\mu) = max_{e'\geq 0, b\geq 0, c\leq w(1+\varepsilon e)} \left\{ -v(b,e') + (1-\mu b)u(c) + \kappa(sb)U(e';\mu') \right\},$$

where $e \geq 0$ represents the mother's endowment of human capital, e' is her investment in her daughters' human capital, and b is the number of births. The value function, $U(e;\mu)$, is parametrized by $\mu \in [0,1]$, the probability of maternal death associated with each birth. The term $(1-\mu b)$ is the probability that a woman will survive childbearing[2].

The function $v(\cdot)$, strictly increasing in both arguments and convex, represents the utility cost of parental investment in children's human capital, which depends on the number of children. The function $u(\cdot)$, twice continuously differentiable, with $u(\cdot) > 0$, $u'(\cdot) > 0$ and $u''(\cdot) \leq 0$, is the utility from mothers' consumption, which depends on baseline income, w,

[2]This framework abstracts from the health burden on pregnancy-related morbidity, which took a very significant toll on women's ability to participate in market work, as well as on their quality of life (Albanesi and Olivetti, 2009). The model can easily be extended to accommodate this feature. We restrict attention to maternal mortality given the lack of data on maternal morbidity.

and their endowment of human capital e. The parameter $\varepsilon \geq 0$ is the return to human capital investment. Mothers with higher human capital enjoy higher utility from consumption if they survive childbirth.

The parameter $s \in (0, 1]$ denotes the youth survival probability, thus, sb is the number of children surviving to adulthood. The function $\kappa(\cdot)$ corresponds to the Barro-Becker dynastic discount factor, with $\kappa(\cdot) \in [0, 1)$ $\kappa'(\cdot) > 0$ and $\kappa''(\cdot) \leq 0$ and $lim_{x\to 0}\kappa'(x) = +\infty$.

The daughters' value function, $U(e'; \mu')$, corresponds to child quality in this model. It depends on the daughter's human capital, and we also index it by the maternal death probability, μ', which may vary over time.[3] Under the stated assumptions, $U'(e; \mu) > 0$ and $U''(e; \mu) \leq 0$. We further restrict $u(\cdot)$ and $v(\cdot)$ to ensure $-v(b, e') + (1 - \mu b)u(c) \geq 0$ for all e, $b \geq 0$ and $\mu \in [0, 1]$, which implies $U(e; \mu) > 0$. In addition, we will impose the following:

Assumption 1 *Let* $V(b, e') := -v(b, e') + \kappa(sb)U(e'; \mu')$ *is strictly concave in* $\{b, e'\}$.

This assumption [4], jointly with the assumptions on $v(\cdot)$, $\kappa(\cdot)$ and the resulting properties of $U(\cdot; \mu)$ implies that the Hessian of $V(b, e')$ is negative definite.

2.1 Predictions

We now derive two properties of the model that give rise to predictions for the effect of a decline in maternal mortality on fertility and investment in daughters' human capital. First, fertility is inversely related to maternal mortality. This property is intuitive, given that higher pregnancy-related mortality probability, μ, increases the loss in the expected utility from consumption associated with a rise in the number of births. The second property is the negative relation between fertility and a mother's endowment of human capital. This result stems from the fact that, as long as maternal mortality risk is positive, a rise in the number of births reduces the probability of enjoying consumption, and the resulting loss in welfare is greater for mothers with higher human capital.

Taken together these properties lead to the prediction that a permanent decline in maternal mortality causes a temporary increase in desired fertility and a permanent rise in women's human capital. Fertility rises for the women who experience the decline after their endowment of human capital has been chosen. Younger women, who experience the maternal mortality decline in their formative years, will enter adulthood with higher human capital.

[3] The youth survival probability, s, baseline income and the returns to human capital also potentially vary across cohorts, but since our focus is on maternal mortality, we omit indexing on these parameters to simplify the notation.

[4] This assumption can be stated in terms of primitives with additional restrictions on the functional forms of $v(\cdot)$, $u(\cdot)$, and $\kappa(\cdot)$.

This increases their opportunity cost of children and reduces their desired fertility relative to cohorts exposed at an older age.

We present these results in two propositions. Proposition 1 derives the effect of a permanent decline in pregnancy-related mortality. Proofs are straightforward and omitted for brevity.

Proposition 1 *Assume that pregnancy-related mortality risk is the same for mothers and daughters, so that $\mu = \mu'$, and that it changes permanently starting with the mother's generation. Then, the optimal response of births and parental investment in human capital satisfies:*

$$\frac{\partial b}{\partial \mu} \leq 0, \tag{1}$$

$$\frac{\partial e'}{\partial \mu} \leq 0, \tag{2}$$

if and only if:

$$[-v_{be'}(b, e') + \kappa'(sb)sU'(e'; \mu')] \geq 0. \tag{3}$$

Proposition 1 states that fertility and mothers' investment in daughters' human capital rise in response to a reduction in maternal mortality if condition 3 holds. This condition implies that the increase in welfare resulting from a marginal rise in investment in daughters' human capital grows with the number of births.

To interpret this condition, note that the marginal benefit of an additional birth is always increasing in daughters' human capital, that is $\kappa'(sb)sU'(e'; \mu') > 0$, under the baseline assumptions. Thus, condition (3) restricts the sign of the term $v_{be'}(b, e')$. If $v_{be'}(b, e') \leq 0$, condition (3) is automatically verified. However, this assumption is unrealistic, since e' represents the level of human capital of all daughters, and presumably, the costs of attaining that level are increasing in the number of children. If $v_{be'}(b, e') > 0$, there is a trade-off between *quality* (that is human capital) and *quantity* of children. Condition (3) restricts the severity of this trade-off. Given that the dynastic discount factor $\kappa(\cdot)$ is concave and satisfies the Inada conditions, this restriction will be always satisfied if initial fertility is low enough. Condition 3 is also more likely to be satisfied for a high value of s.

To summarize, desired fertility and daughters' human capital investment rise in response to a permanent reduction in maternal mortality, as long as the marginal value of parental investment in children's human capital is not decreasing in the number of children.

Proposition 2 characterizes the sensitivity of fertility and investment in daughters' human capital to a mothers' human capital for given maternal mortality.

Proposition 2 *Under the baseline assumptions:*

$$\frac{\partial b(e;\mu)}{\partial e} \leq 0. \tag{4}$$

If, in addition, condition (3) holds, then:

$$\frac{\partial e'(e;\mu)}{\partial e} \geq 0. \tag{5}$$

Based on Proposition 2, fertility falls with a mother's endowment of human capital. The inequality in (4) is strict if the maternal mortality rate is strictly positive. For given μ, an increase in the number of births reduces the probability that the mother will enjoy utility from consumption. The corresponding loss in welfare is increasing in the mother's human capital.[5]

Investment in daughters' human capital can rise or fall with the mother's human capital in general, since higher maternal human capital generates an increase in the demand for child quality but produces a negative income effect on maternal investment in daughters' education. Condition (3) is necessary and sufficient for the first effect to prevailing, leading to a positive relation between a mother's human capital and her investment in her daughters' human capital.[6]

It is also straightforward to show that under the conditions in Propositions 1 and 2, the rise in fertility and women's human capital is increasing in the magnitude of the reduction in μ. Thus, economies with initially high maternal mortality that experience a larger reduction in this variable would exhibit a larger baby boom and bust cycle.[7] It is also straightforward to verify that the rise in human capital and the corresponding bust in fertility will be greater for higher values of the returns to human capital, ε.

[5]Based on a similar logic, fertility also decreases with baseline income, w, and the returns to human capital investment, ε, in the model, replicating the negative empirical relation between mother's income and fertility (Jones and Tertilt, 2007).

[6]Agents have perfect foresight in the model. In practice, there may have been delays in the diffusion of information on the maternal mortality decline, or uncertainty on whether it was indeed permanent. In case of a temporary decline in maternal mortality, fertility and human capital investment rise, though in this case the rise in women's human capital is not permanent. The model can also be adapted to allow for delays in the diffusion of information.

[7]Fertility also responds to the youth survival probability, s. It can be shown that under Condition (3) fertility declines if s increases, and that, if fertility declines, then investment in children's human capital rises. This property is consistent with the historical experience of the advanced economies, where a reduction in youth mortalities starting in the mid 1850s was associated with a decline in fertility (Preston, 1978, Haynes and Preston, 1991) and a rise in human capital (Becker, Murphy and Tamura, 1990).

2.2 Discussion

Propositions 1 and 2 taken together deliver a set of predictions for the response of fertility and women's human capital to a permanent decline in maternal mortality under condition (3). By Proposition 1, women who experience a permanent decline in pregnancy-related mortality as adults increase their desired fertility and invest more in their daughters' human capital. Younger women who experience this decline in formative years will benefit from greater parental investments in human capital and, by Proposition 2, they will choose a lower number of births. This property leads to a boom-bust pattern in the response of fertility to a permanent decline in maternal mortality. Proposition 2 also implies that a decline in maternal mortality causes a permanent rise in women's human capital. The effect on fertility once the advances in maternal health are exhausted may well be negative, if the returns to human capital are high enough.

Condition (3) will hold if initial fertility is low enough, since $\kappa'(sb)$ is decreasing in the number of births. High values of the youth survival probability, s, also contribute to Condition (3) being satisfied, since they increase the marginal benefit of investment in children's human capital. Finally, higher values of baseline income, w, and greater returns to human capital, ε, increase the value of $U'(e';\mu')$ and make it more likely that Condition (3) will hold. Thus, Propositions 1 and 2 imply that the drop in pregnancy-related mortality will generate a temporary rise in fertility and a permanent rise in women's human capital in economies that initially have low fertility and high youth survival probability, and have attained sufficiently high levels of income and returns to human capital. Moreover, the rise in fertility will be more pronounced if initial maternal mortality is high, and the rise in women's human capital and associated decline in fertility will be larger if income or the returns to human capital are high.

3 Empirical Analysis

The theoretical analysis of the previous section delivers a set of predictions on the differential effects of improvements in maternal health of fertility and women's human capital as a function of initial conditions and country characteristics. These predictions can be evaluated with time series data on maternal mortality, fertility, infant mortality and indicators of economic development and educational attainment for a broad set of countries.

We will separate the analysis in two parts. The first involves a group of 24 advanced and emerging economies for which the data is available from 1900. In this section, we will also conduct a case study of Sweden, for which data is available since 1800. The second part of the analysis comprises a descriptive study of the link between maternal mortality and fertility in developing economies for the post-war period.

3.1 Descriptive Evidence

Figure 1 presents the time series of maternal mortality between 1900 and 2000 for the countries included in the analysis. These economies are similar to the U.S in many respects, even if they exhibit considerable variation in maternal and infant mortality rates, and fertility. The decline in maternal mortality is sizable during the sample period. The maternal mortality ratio starts dropping sharply in the late 1930s in most countries, possibly driven by the introduction of sulfa drugs in 1936 (Jayachandran, Lleras-Muney and Smith, 2009), albeit from very different initial levels. There is a very strong convergence in maternal mortality across countries during the 1940s and 1950s, before the rate reaches modern levels in the early 1960s for all countries, and in the mid 1970s for Italy, Japan and Portugal.

In Section 3.1.1, we describe the joint behavior of maternal mortality, infant mortality and fertility. In Section 3.2, we conduct an event study analysis of the impact of the maternal mortality decline on fertility to assess the theoretical predictions derived above.

3.1.1 Cross-Country Variation in Maternal Mortality, Infant Mortality and Fertility

Figure 2 plots the time series of maternal mortality, infant mortality and fertility for the group of advanced economies for which maternal mortality data has been assembled starting in 1900 (figure 2). These comprise the U.S., the U.K., Canada, Australia, New Zealand, Ireland (Anglo-Saxon countries), Denmark, Finland, Netherlands, Norway and Sweden (Nordic countries), and Austria, Belgium, France, Switzerland (continental European countries), Greece, Italy, Portugal and Spain (Mediterranean countries) and Japan.

The decline in both maternal and infant mortality is sizable during the sample period. In many of these countries the maternal mortality ratio starts dropping sharply in the 1930s and stabilizes to a virtually constant level by 1960. For all countries, the decline of infant mortality is more gradual and continues to the current years. Despite the considerable cross-country variation, the initial levels of maternal and infant mortality, and the time path of fertility display very similar behavior within country groups.

The Anglo-Saxon countries and the Nordic countries exhibit a similar time variation in infant and maternal mortality, though both variables are initially much lower among the Nordic countries. In the 1900-1935 period, maternal mortality is well above 50 deaths per 10,000 live births in Anglo-Saxon countries, whereas it is closer to 30 in Nordic countries.

Initial levels of infant mortality are more similar across these two groups, ranging between 100 and 150 infant deaths per 1,000 live births in the 1920s. The U.S. stands out as being the country with the highest maternal mortality ratio for the period 1900-1930 (above 80 maternal deaths per 10,000 live births), though the infant mortality ratio starts to decline earlier in the U.S. than in the U.K. or Canada. Sweden exhibits the lowest levels of initial maternal and infant mortality among these two groups.

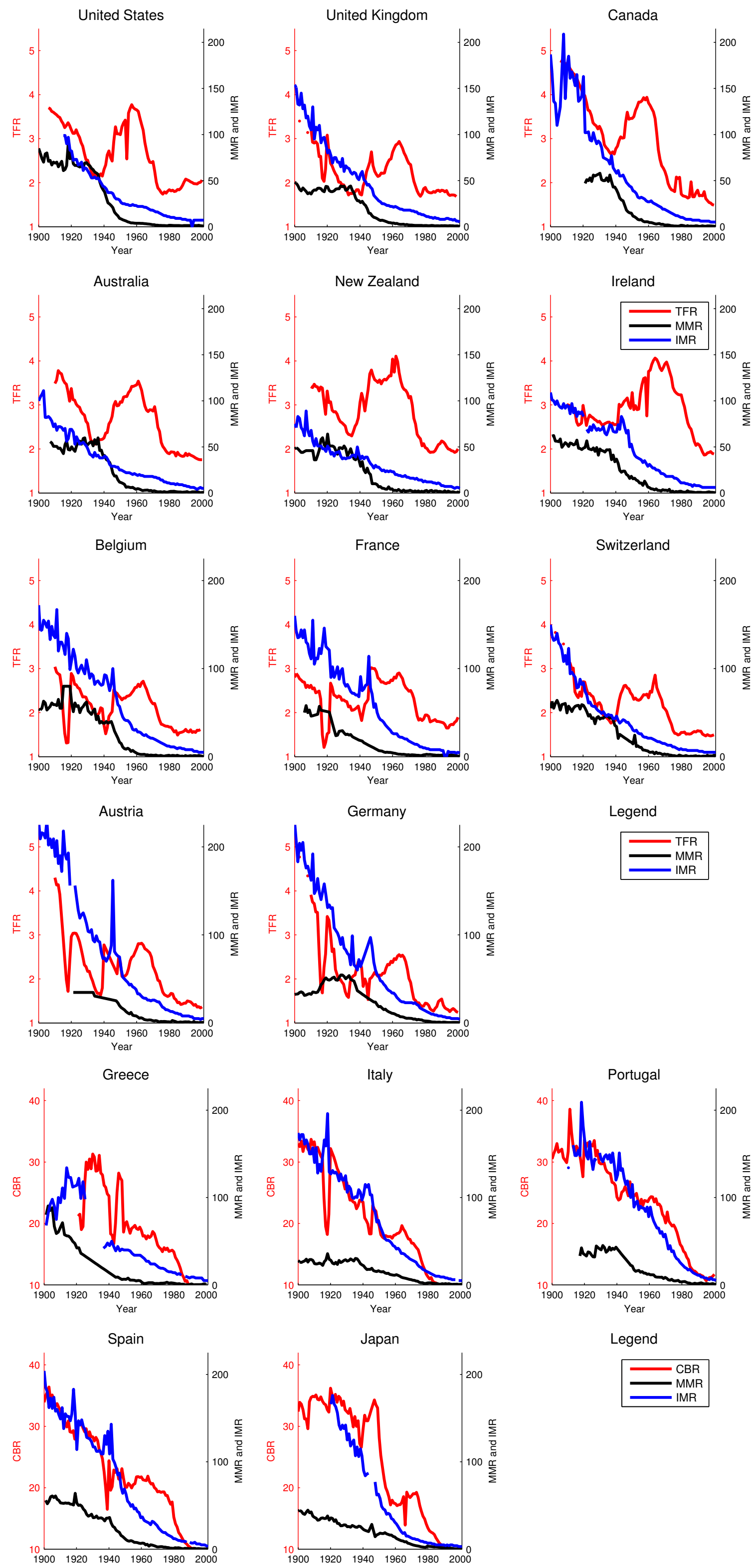
The continental European countries can be split in two groups. Belgium, France and Switzerland exhibit a path of maternal and infant mortality similar to the Anglo-Saxon and Nordic countries. Initial levels of maternal and infant mortality are also similar. By contrast, Austria, Greece, Italy, Portugal and Spain display very high initial infant mortality. For Greece, Italy and Spain, the infant mortality ratio exceeds 200 deaths per 1,000 live births in the 1930s, and infant mortality in Portugal is still close to that level in the early 1960s. Maternal mortality is comparable to Nordic and Anglo-Saxon countries in the post-war period for these four countries. Japan exhibits a pattern of infant and maternal mortality that closely resembles the continental European countries.

The patterns of fertility also display similarities within country groups. All Anglo-Saxon countries experience a sharp rise in fertility between the late 1930s and the late 1950s,[8] with a rise in the crude birth rate well in excess of 35%. The baby booms in the U.S. and Australia are the largest and most protracted. The Nordic countries experience similar pattern, though the baby booms in these countries are smaller and mostly shorter. The pre-boom crude births rates are similar, at approximately 20 births per 1,000 population, for countries in these groups. All Anglo-Saxon and Nordic countries experience a sharp and protracted decline in the crude birth rate after the baby boom. Their crude birth rates attain unprecedentedly low levels, mostly below 15 births per 1,000 population.

Austria, Belgium, France and Switzerland also experience a rise in fertility between 1940 and and the early 1960s. However, this rise is considerably smaller than in the Anglo-Saxon and Nordic countries. In Austria, Belgium and Switzerland fertility declines for a decade starting in the mid-1960s and then stabilizes, whereas there is virtually no decline in France. Greece, Italy, Portugal and Spain by contrast experience a continuous decline in fertility for the entire sample period. All countries in this group display crude birth rates greater than 30 per 1,000 population in the 1920s and 1930s, well above the values for Anglo-Saxon and Nordic countries, and Belgium, France and Switzerland in the same period. In Japan, the crude birth rate is relatively high, around 30 births per 1,000 population, between 1900 and the early 1950s and then drops sharply to just under 20 births per 1,000 population in the 1970s, and continues to decline in the following decades.

[8]Fertility declines temporarily in the immediate aftermath of World War II in the U.K.

Figure 2: Maternal Mortality, Infant Mortality and Fertility



Sources: Maternal mortality from Loudon (1992), UN Demographic Yearbook (Various issues), Meigs (1917). Crude birth rates from Mitchell (1998).

3.1.2 Baby Booms and Baby Busts

We now identify the countries which experience baby booms and baby busts. For this purpose, a baby boom (bust) is defined as a 10% or greater increase (reduction) in fertility over a span of 15 years. We use two measures of fertility, the crude birth rate, which is available for all countries, and the total fertility rate, which is available for all countries except Greece. Table 1 reports the year in which a baby boom or bust begins, and the corresponding change in fertility in the subsequent 15 years. Empty cells correspond to countries that do not experience a boom/bust.

All countries except Greece, Italy, Japan and Portugal experience a baby boom in the total fertility rate (TFR) and the crude birth rate (CBR). For the total fertility rate, the median year in which the baby booms occur is 1938 and the median change in fertility is +34%. The U.S. experiences the largest baby boom, with a rise in total fertility of 45% starting in 1938. New Zeland and Austrialia experience a 42% rise in TFR, starting in 1937. Norway and Sweden experience a rise in TFR equal to 40% and 37%, respectively, starting in 1938 and 1934. All other countries except Spain and Ireland experience a rise in fertility between 25% and 35% beginning between 1937 and 1941. Ireland and Spain experience a baby boom starting in 1953 and 1955, respectively, though while Ireland's total fertility rate grows by 31% in the subsequent 15 years, Spain's only grows by 15%. Results are similar for the crude birth rate, except for the U.K, which does not experience and event in terms of the crude birth rate. This is due to the fact that the WWII destruction in the U.K. causes a delay in childbearing for the affected cohorts. Such impact on the timing of fertility affects the crude birth rate but does not affect the total fertility rate. The correlation between initial fertility and the size of the baby boom is -0.30 for TFR, but not significant, while it is small and positive for CBR.

All countries in the sample experience sizable baby busts, in terms of both measures of fertility. The median change in fertility for the baby bust episodes is -37% for TFR (-31% for CBR), and the median start year is 1965 for TFR (1964 for CBR). All countries except Greece and Japan experience the baby busts in the 1960 and 1970s. As previously noted, Greece and Japan do not experience a baby boom, therefore the year reported in the table is one in which an intensification of the ongoing decline in fertility occurs. There is a negative correlation between initial fertility and the size of the baby bust for CBR and a positive correlation for TFR, though both are not significant.

The median difference between the start of the baby bust and the start of the baby boom (for countries which experience one) is 25 years for TFR and 23 for CBR.

TABLE 1: Baby Booms and Baby Busts

	Baby Booms						Baby Busts							
	Year that marks the start of a baby boom	*Initial Fertility*	*% rise in fertility in the subsequent 15 years*	*Year that marks the start of a baby boom*	*Initial Fertility*	*% rise in fertility in the subsequent 15 years*	*Year that marks the start of a baby bust*	*Years since start of baby boom*	*Initial Fertility*	*% decline in fertility in the subsequent 15 years*	*Year that marks the start of a baby bust*	*Years since start of baby boom*	*Initial Fertility*	*% decline in fertility in the subsequent 15 years*
		CBR			**TFR**			**CBR**				**TFR**		
1 Australia	1937	17.0	**37%**	**1937**	**2.2**	42%	1962	25	22.4	-22%	1962	25	3.4	-34%
2 Austria	1938	13.7	**18%**	**1938**	**1.7**	27%	1966	28	18.3	-35%	1965	27	2.7	-38%
3 Belgium	1944	14.0	**22%**	**1944**	**1.8**	34%	1929	-15	18.8	-25%	1964	20	2.6	-34%
4 Canada	1938	20.6	34%	1939	2.7	**34%**	1958	19	28.0	**-41%**	**1961**	22	**3.9**	-50%
5 Denmark	1936	17.8	**12%**	**1938**	**2.0**	29%	1966	28	17.4	**-34%**	**1965**	27	**2.6**	-36%
6 Finland	1936	19.5	32%	1937	2.4	**34%**	1950	13	26.1	**-32%**	**1960**	23	**2.8**	-40%
7 France	1941	14.3	30%	1941	2.0	33%	1963	22	18.0	-21%	1965	24	2.8	-33%
8 Greece							1973		16.5	-30%	1939		3.6	-33%
9 Ireland	**1940**	**19.3**	10%	1953	3.0	31%	1974	21	22.1	-23%	1971	18	3.9	-31%
10 Italy							1965		18.7	-32%	1972		2.4	-41%
11 Japan							1948		32.8	-47%	1942		4.1	-42%
12 Netherlands	1940	20.3	8%	1940	2.6	**17%**	1964	24	21.7	-41%	1963	23	3.2	**-47%**
13 New Zealand	1936	18.1	46%	1937	2.2	**42%**	**1963**	26	**26.1**	-31%	1962	25	3.4	-34%
14 Norway	1938	14.9	28%	1938	1.8	40%	1963	25	17.5	-22%	1967	29	2.9	-40%
15 Portugal							1968		22.7	-31%	1972		2.6	-31%
16 Spain				**1955**	**2.5**	15%	1973	18	19.5	-41%	1971	16	2.9	-42%
17 Sweden	1936	14.2	23%	1934	1.8	37%	1947	13	19.3	-26%	1966	32	2.3	-30%
18 Switzerland	1939	15.5	**13%**	**1939**	**1.8**	28%	1966	27	18.8	**-38%**	**1965**	26	**2.4**	-37%
19 United Kingdom	1940	14.6	**9%**	**1937**	**1.8**	29%	1965	28	18.2	**-31%**	**1965**	28	**2.8**	-36%
20 United States	1938	17.9	35%	1938	2.2	**45%**	1957	19	24.6	**-31%**	**1960**	22	**3.7**	-45%
Median	**1938**	**17.0**	**23%**	**1938**	**2.1**	**34%**	**1964**	**23**	**19**	**-31%**	**1965**	**25**	**3**	**-37%**
Correlation between initial fertility and change		**0.1**			**-0.3**				**-0.5**				**0.1**	

Sources: CBR (live births per 1,000 population) from Mitchell (1998), TFR from Chesnais (1991). Variables are 5 year centered moving averages of original series.

3.1.3 Summary

This descriptive analysis can be summarized by identifying the following groups of countries displaying similar behavior:

- Anglo-Saxon (US, UK, Canada, Australia, New Zealand, Ireland):
  - high initial maternal mortality, relatively low initial infant mortality, relatively low initial fertility
  - large mid-century fertility boom and bust, except for Ireland which experiences a late and smaller baby boom
- Nordic (Denmark, Finland, Netherlands, Norway and Sweden):
  - lower (in comparison to the Anglo-Saxon countries) initial maternal mortality, lower initial infant mortality, similar initial fertility
  - mid-century fertility boom and bust
- Continental European (Austria, Belgium, France and Switzerland):
  - lower (in comparison to the Anglo-Saxon countries) initial maternal mortality, similar low initial infant mortality, similar low initial fertility
  - small mid-century fertility increase starting in the early 1940s, slow fertility decline from the mid 1960s
- Mediterranean (Greece, Italy, Portugal and Spain) & Japan:
  - very low (in comparison to the Anglo-Saxon countries) initial maternal mortality, very high initial infant mortality, very high initial fertility
  - continuous decline in fertility for the entire period, except for Spain which experiences a late and small baby boom

This summary suggests that these economies can be grouped that the decline in maternal mortality between the 1930s and the mid 1950s is associated with a baby boom only in those countries where initial fertility and initial infant mortality are low enough, consistent with the theory. We will now use an event study analysis of the decline in maternal mortality to evaluate this hypothesis.

3.2 Event Study

We are interested in identifying episodes of significant maternal mortality reduction similar to the ones that took place in the U.S., where maternal mortality dropped by more that 95% in 20 years starting in the 1930s (Albanesi and Olivetti, 2010). Such episodes, which we will refer to as events, will be characterized by a time span over which the reduction occurred and by the percentage amount of the reduction. Since in all the countries in the sample, maternal mortality declines permanently[9], we will take the earliest such event. Also, we will use a 5 year centered moving average of the maternal mortality rate in order to obtain a smoother series. For each country c, we identify t^* as the year in which such an event begins. We will then examine the behavior of fertility in a window of $\{-10, +40\}$ years around t^*. This approach allows us to isolate the direction, magnitude and timing of the response in fertility. We will also use these results to structure a formal longitudinal analysis of the relation between fertility and maternal mortality.

As discussed in Section 3.1.1, there is considerable heterogeneity in the behavior of maternal mortality across the countries in the sample, and we would like to capture any and all episodes of significant and rapid maternal mortality decline. To identify a suitable definition of event, we conduct a sensitivity analysis on the time span and the size of the maternal mortality drop that define of event. Table 2 reports selected results from this exercise, displaying t^* and the level of maternal mortality at t^* for each country in the sample, using data from 1925 to 1900. The criteria for identifying an event become increasingly stringent going from left to right in the table. The time span is set at either 20 or 10 years, while the percentage drop rises from 70 to 90 percent. As can be seen from the first column, all countries experience at least a 70% reduction in maternal mortality in 20 years. The median value of t^* is 1933, while the median value of initial maternal mortality is 41. Countries that experience the event earlier have higher initial maternal mortality, with a correlation of -0.71. If we require that the 70% reduction occurs within a 10 year span, then several countries do not experience an event. The median value of t^* is now 1944, but for several countries the event occurs at very low initial levels of maternal mortality, with the correlation between these variables at -0.95. Requiring an 80% reduction in maternal mortality over the next 20 years implies a median value of t^* at 1937. The median initial maternal mortality is 35 deaths per 10,000 live births, and the correlation between t^* and initial maternal mortality is -0.79. Finally, if we require the drop in maternal mortality to be at least 90% in the subsequent 20 years, only 5 countries experience an event. Of these, Denmark, Norway and Sweden experience the event very late (after 1955) and at a very low level of maternal mortality.

[9]The only exception is Denmark where maternal and infant mortality temporarily rise during World War II.

Belgium, Finland and the U.S. experience the event in 1943, 1944 and 1935, respectively, at high levels of maternal mortality.

The second and fourth event definitions exclude many countries in the sample that experience sizable reductions in maternal mortality and identify counterfactually late episodes of maternal mortality reduction.[10] Thus, we will adopt the third definition, corresponding to an 80% decline in maternal mortality over 20 years, as the benchmark, and we will also conduct the analysis for the first definition for robustness.

We first consider the full sample of countries to experience an event, and present the results in figure 3. Period 0 in the charts corresponds to t^*. We report the mean and the median of fertility across countries in each year t of the event window, and the 5% confidence intervals for the hypothesis that fertility at t is equal to fertility at t^* for $t > \tilde{t}$, where $\tilde{t} > t^*$ is the year with the lowest fertility between t^* and $t^* + 25$[11]. We report the mean and median of maternal mortality in the event window (NW panel) and present results for three fertility variables, the total fertility rate (NE panel), the detrended TFR (SW panel) and the detrended crude birth rate (SE panel)[12]. The TFR is rescaled to 1 at t^* for each country. The plots clearly suggest that both the median and mean total fertility rate rise starting at $t^* + 10$, reach a plateau at $t^* + 20$, and start declining at $t^* + 35$. The peak of the boom corresponds to a rise in median TFR of approximately 25% from $\tilde{t}$. The crude birth rate starts rising at $t^* + 5$ and peaks at $t^* + 18$, when it stabilizes before declining at $t^* + 33$. For all fertility measures, the hypothesis that fertility does not rise at $t > \tilde{t}$ is rejected at a 5% confidence level.

[10]A 90% reduction in maternal mortality when it has already reached moderns levels, that is below 5 deaths per 10,000 live births, does not correspond to a significant decline in the maternal mortality risk or in the health costs of pregnancy, since maternal mortality remains in the same range.

[11]Thus, $\tilde{t}$ corresponds to the first year in the event window in which fertility starts rising after t^* for countries that experience a baby boom. A horizontal axis is plotted at the fertility level prevailing at $\tilde{t}$.

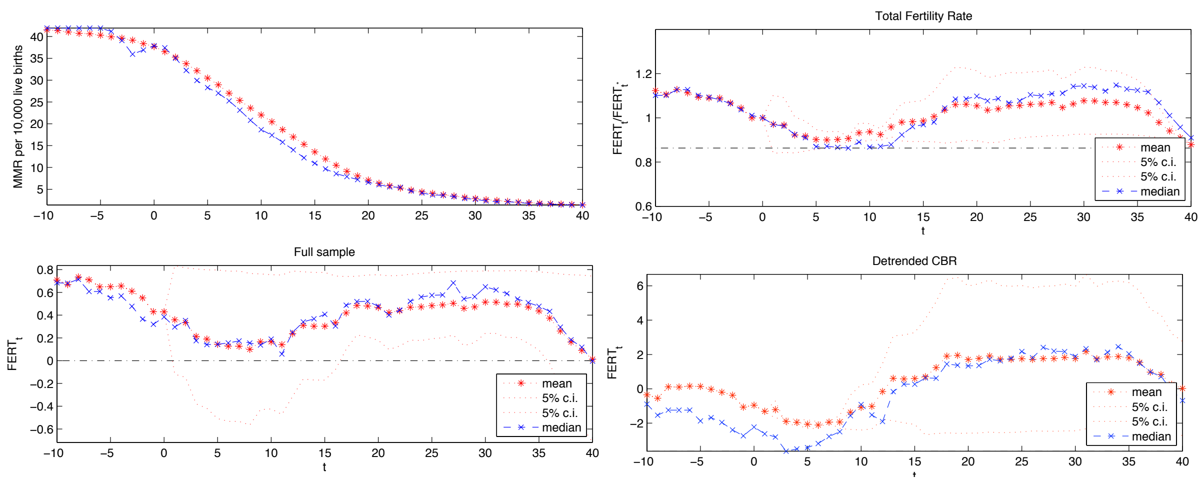
[12]The detrended series are obtained by subtracting a simple linear time trend from the original series.

Table 2: Maternal Mortality Reduction Events and Baby Boom Episodes

		Year that marks x% or greater drop in maternal mortality in the next y years							
		1		**2**		**3**		**4**	
		x=70, y=20		**x=70, y=10**		**x=80, y=20**		**x=90, y=20**	
		Year	***Initial MMR***	***Year***	***Initial MMR***	***Year***	***Initial MMR***	***Year***	***Initial MMR***
1	Australia	1930	55	1942	37	1933	54		
2	Austria	1940	29			1945	26		
3	Belgium	1932	54	1944	37	1935	47	1943	38
4	Canada	1931	55	1945	26	1934	52		
5	Denmark	1935	38			1935	37	1955	6
6	Finland	1931	69	1944	40	1933	65	1944	40
7	France	1933	27			1929	30		
8	Greece	1932	60			1938	41		
9	Ireland	1935	46	1956	11	1943	28		
10	Italy	1955	14			1959	12		
11	Japan	1954	18			1956	17		
12	Netherlands	1933	32			1939	26		
13	New Zealand	1930	48	1942	31	1932	47		
14	Norway	1934	29			1939	27	1957	6
15	Portugal	1942	39			1968	8		
16	Spain	1933	37			1943	28		
17	Sweden	1933	33	1964	2	1933	33	1955	5
18	Switzerland	1936	45	1969	3	1939	38		
19	United Kingdom	1930	42			1933	42		
20	United States	1930	67	1939	45	1930	67	1935	59
	Median	**1933**	**41**	**1944**	**31**	**1937**	**35**	**1950**	**22**
	Correlation between year and initial MMR	-0.71		-0.95		-0.79		-0.99	

Maternal mortality is measured per 10,000 live births and corresponds to a 5 year centered moving average of the raw series. Initial MMR corresponds to the rate of maternal mortality prevailing at the start of the event.

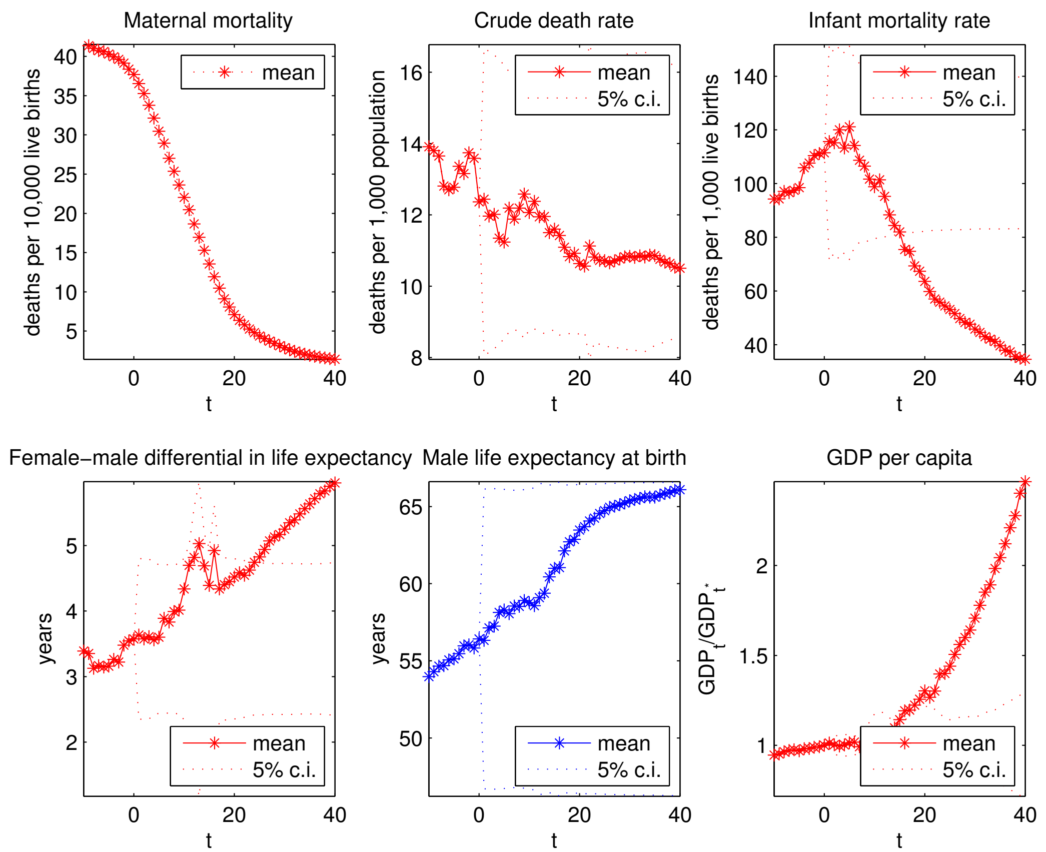
FIGURE 3: Response to the Maternal Mortality Decline, Fertility



Sources: TFR from Chesnais (1992). CBR from Mitchell (1998).

We also examine the behavior of additional variables connected or potentially connected to health and fertility in the event window. Figure 4 reports the behavior of the crude death rate, the male life expectancy at birth, the female-male differential in this variable, as well as infant mortality and GDP per capita in the event window, with 5% confidence intervals for the hypothesis that the value of these variables at $t > t^*$ is equal to their value at t^*. The crude death rate declines between $t^* - 3$ and $t^* + 20$, while male life expectancy rises between $t^* + 10$ and $t^* + 22$, but is virtually constant in the rest of the window. By contrast, the female-male differential in life expectancy, which is constant between the start of the event window and $t^* + 5$, rises sharply in years $8 - 12$ after t^*, and settles on a positive trend in year $t^* + 22$, going from just over three years at t^* to over 5 years at $t^* + 40$. Infant mortality rises until $t^* + 6$ and then declines sharply for the rest of the event window. GDP per capita is virtually constant until $t^* + 15$, and then rises by a factor of 2.5 between $t^* + 15$ and the end of the event window. This suggests that there was indeed a connection between the decline in maternal mortality and the rise in female life expectancy relative to males, though there is no clear direct temporal relation between maternal mortality and male life expectancy. The sharp decline of infant mortality at the end of the event window should be associated with a decline in fertility, according to the theory and may also have contributed to the baby bust that can be observed in figure 3 for all measures of fertility. Finally, the behavior of GDP per capita within the event window does not exhibit a pattern that suggests a causal relation with maternal or infant mortality.

FIGURE 4: Life Expectancy, CDR, Infant Mortality and GDP in the Event Window



Sources: Infant mortality from Mitchell (1998). GDP per capita from Maddison (2007). Life expectancy by gender from Human Mortality Database.

The theory predicts that the fertility response to the maternal mortality decline should depend on initial maternal mortality, as this determines the size of the decline, and initial fertility and initial infant mortality, as these variables affect the intensity of the quality/quantity trade-off in fertility choice. We explore this dependency, and present the results in a series of plots in figure 5.

First, we group countries by whether their maternal mortality ratio at t^* is below the median (Low initial MMR) or above the median (High initial MMR) at t^*. For each group of countries, the top chart displays the behavior of maternal mortality in the event window for countries in the group, and the bottom chart displays the behavior of fertility[13]. The baby boom following the maternal mortality drop is more pronounced in high initial maternal mortality countries, where median and mean fertility start rising at $\tilde{t} = t^* + 8$ and peak at $t^* + 29$, with an overall increase of 50%. Fertility starts a rapid decline at $t^* + 35$.

[13]We only report results for TFR. The findings are similar for the detrended TFR and the crude birth rate.

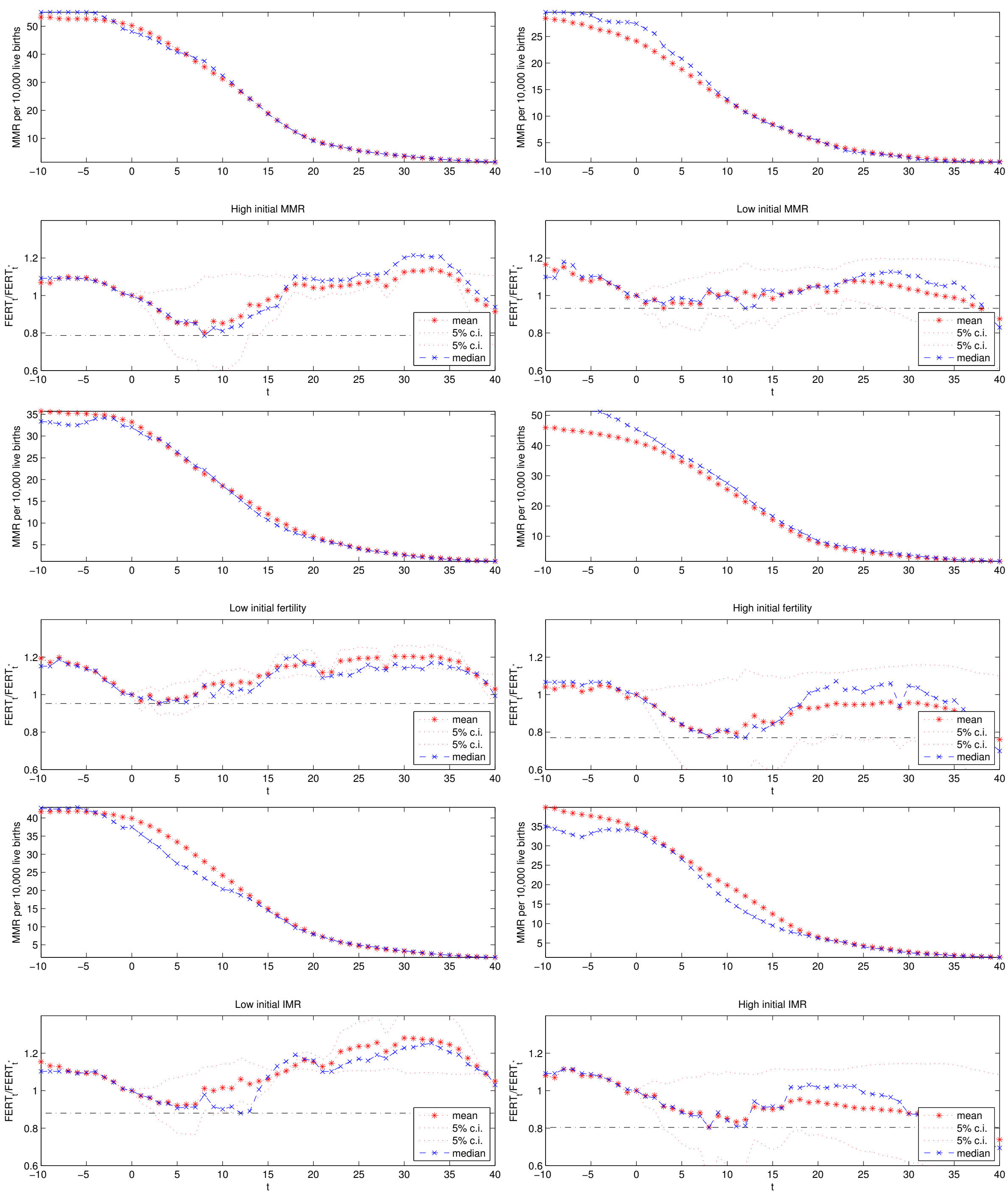
Low initial maternal mortality countries also experience a modest rise in fertility, though it is not statistically significant, whereas for the high initial maternal mortality countries, the hypothesis that fertility at t for $t > t^*$ is the same as fertility at $\tilde{t}$, is rejected at 5% significance for $t \in [16, 35]$.

The theory also predicts that only countries with sufficiently low initial fertility and infant mortality will exhibit a boom-bust response in fertility, as they will satisfy condition 3. Thus, we group countries with fertility at t^* smaller than the median (Low initial fertility), and those with fertility above the median (High initial fertility). These plots are presented in the center panel of figure 5. The low initial fertility countries exhibit a sizable positive response of fertility, which starts rising at $\tilde{t} = t^* + 5$ and plateaus at $t^* + 25$ and starts dropping at $t^* + 35$. Fertility rises by over 30% during the boom, and is higher at $t \in [8, 38]$ relative to $\tilde{t}$ at a 5% level of significance. The countries with high initial fertility display a small rise in fertility, though the hypothesis that fertility after the maternal mortality decline is the same as at $\tilde{t}$ cannot be rejected.

Similarly, we group countries according to whether their infant mortality ratio at t^* is below the median (Low initial IMR) or above the median (High initial IMR), and present the corresponding plots in the lower panel. Initial maternal mortality is very similar in both groups of countries. For the low initial infant mortality countries, fertility starts rising at $t^* + 6$ and peaks at $t^* + 25$ after rising approximately 25%. In high initial infant mortality countries, fertility rises by just under 10% between $t^* + 12$ and $t^* + 25$, but the hypothesis that it does not rise cannot be rejected, while it is rejected at 1% level of significance for the initial low infant mortality countries.

These findings confirm that higher initial maternal mortality, and lower initial fertility and infant mortality are associated with a larger rise in fertility in response to a decline in maternal mortality.

Figure 5: Fertility Response to the Maternal Mortality Decline, by Initial Maternal Mortality, Fertility and Infant Mortality

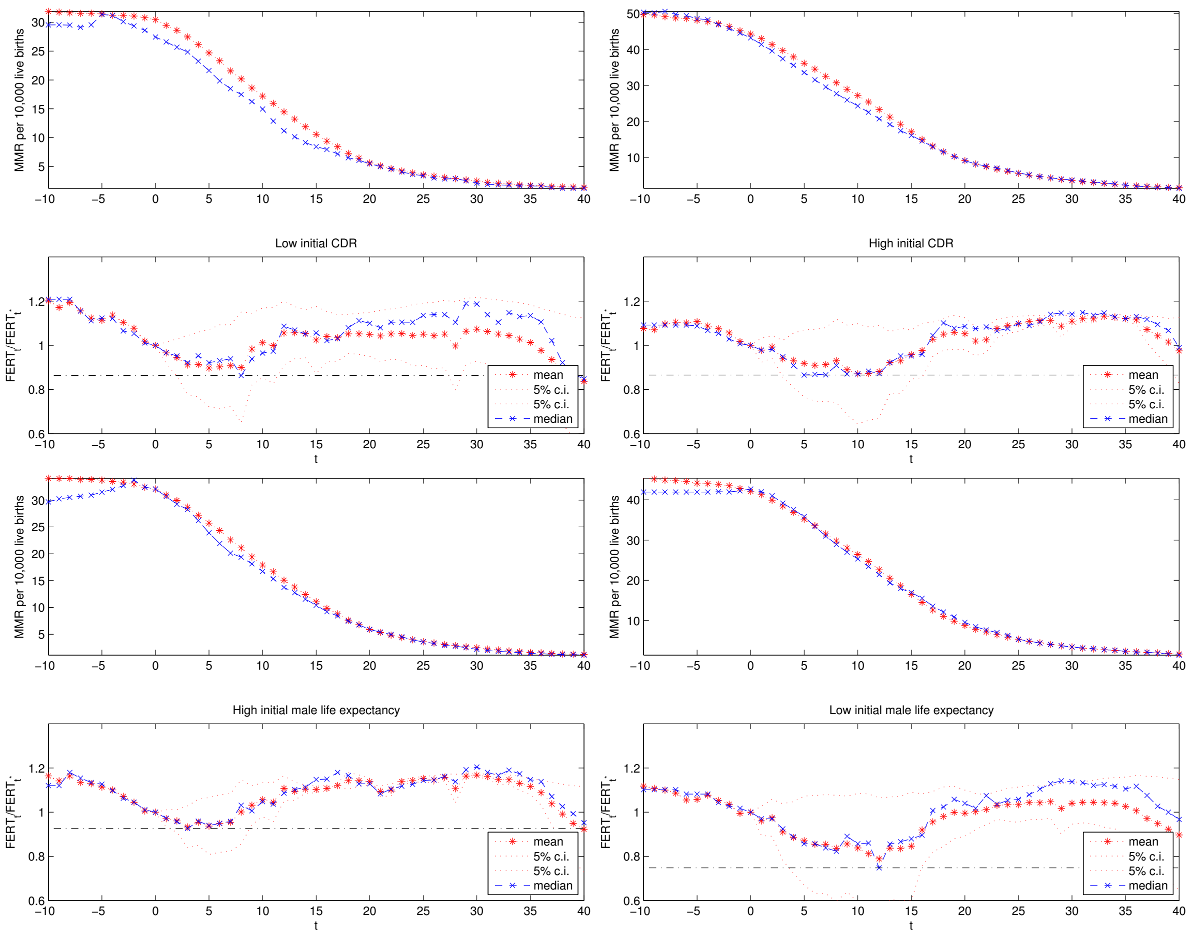


Sources: MMR (maternal deaths per 10,000 live births) Loudon (1992), UN Demographic Yearbook (Various issues), Meigs (1917), WHO and national sources compiled by the author. TFR from Chesnais (1991).

We now examine how other initial conditions influence the behavior of fertility subsequent to the maternal mortality decline. The correlation between initial maternal mortality at t^* and the initial conditions is displayed in Table 9 in Appendix C.

We first consider health conditions, proxied by the crude death rate and male life expectancy at age 0. The results are displayed in figure 6. Lower crude deaths rates and higher male life expectancy should be associated with higher returns to human capital, which, according to the theory, make it more likely that condition (3) will hold. One problem with this interpretation is that, as can be seen in Table 9, the initial crude death rate and male life expectancy display a strong correlation (positive and negative, respectively) with initial maternal mortality, even as the time path of these variables within the event window does not reflect the path of maternal mortality. Given this, the initial crude death rate and life expectancy can serve as an instrument for initial maternal mortality. Indeed, countries with above median crude birth rate and below median male life expectancy at birth, as can be seen in the figure, experience a strong positive response of fertility to the maternal mortality reduction. The total fertility rate starts rising at $t^* + 12$ and peaks at $t^* + 20$ where it plateaus, before starting to fall at $t^* + 35$.

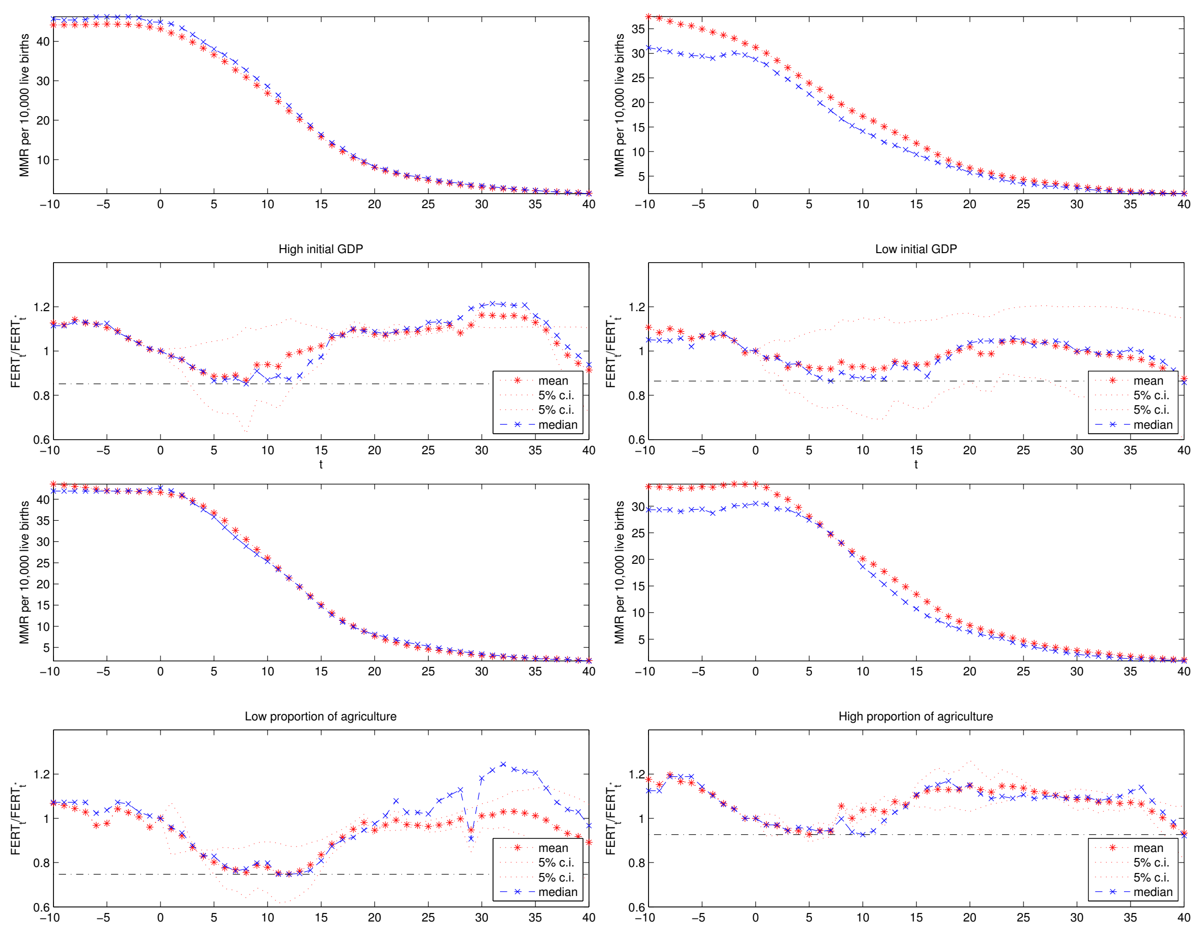
FIGURE 6: Fertility Response to the Maternal Mortality Decline, by Infant Mortality, Crude Death Rate and Male Life Expectancy



Sources: MMR (maternal deaths per 10,000 live births) Loudon (1992), UN Demographic Yearbook (Various issues), Meigs (1917). CBR (live births per 100,000 population) Mitchell (1998).

We now examine the role of initial economic conditions. We posit that GDP per capita is positively related to baseline income, while the proportion of output from agriculture is negatively related to the returns to human capital, and split the countries by their initial level of these variables. The corresponding plots of maternal mortality and the fertility response are presented in figure 7. According to the theory, higher values of baseline income and returns to human capital make it more likely that condition 3 will hold, which should lead to a boom and bust response in fertility. On the other hand, higher baseline income and returns to human capital increase the opportunity cost of children, which in turn may depress fertility and dampen the boom. The boom bust response in fertility is more pronounced in high initial GDP countries, where fertility rises significantly by $t^* + 15$ and peaks at $t^* + 30$, and starts dropping sharply at $t^* + 35$. Fertility rises by over 40% at the peak of the boom. By contrast, in low initial GDP countries, fertility significantly rises only at $t^* + 23 - (t^* + 26)$, and only by 20% at the peak. High initial GDP countries display higher initial maternal mortality rates, which may explain their pronounced fertility response. The response of fertility is much stronger in countries with low initial proportion of agriculture, which also have much higher initial maternal mortality. Fertility starts rising at $t^* + 10$ and peaks at $t^* + 32$, with mean fertility rising by 11% at the peak, and median fertility rising by 33%. Countries with low initial proportion of agriculture are the ones displaying the highest levels of initial maternal mortality.

FIGURE 7: Fertility Response to the Maternal Mortality Decline, by Economic Conditions



Sources: GDP from Maddison (2007), proportion of GDP from agriculture from Mitchell (2008).

Next, we turn to the role of lagged GDP and lagged GDP changes, with results displayed in 8. The purpose of this exercise is twofold. We are interested in how lagged GDP and GDP changes affect the fertility response to a decline in maternal mortality, and in detecting whether the path of maternal mortality during the event varies significantly with these variables. The top panel displays the path of maternal mortality and fertility in the event window based on their initial values of initial lagged GDP per capita and lagged detrended

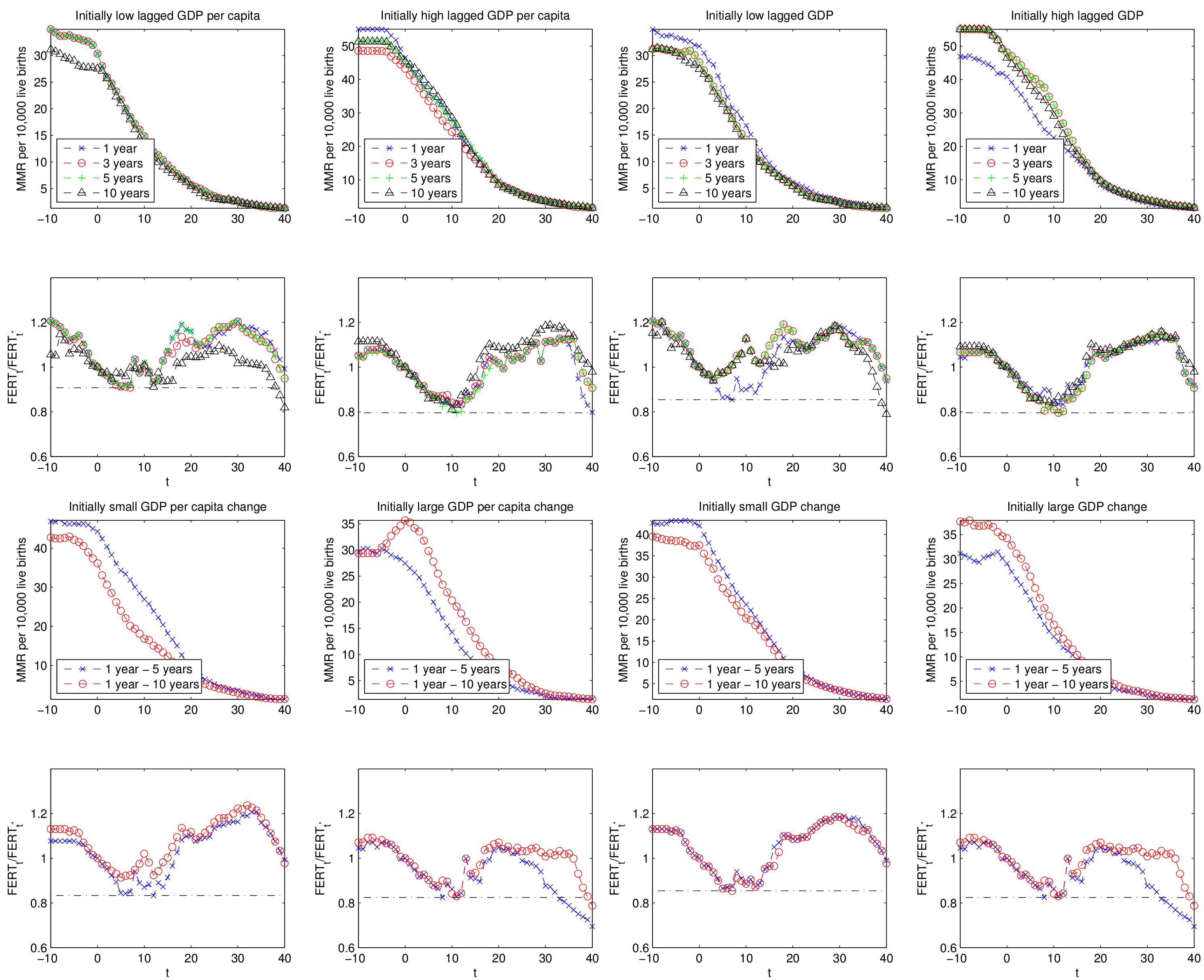
GDP.[14] We consider 1, 3, 5, and 10 year lags. A high value of detrended GDP can be interpreted as corresponding to a cyclical expansion in the economic activity, whereas a low value may capture a cyclical contraction in economic activity. Since GDP variations may in part be driven by demographic factors, such as fertility or immigration, we also consider GDP per capita. As can be seen from the chart, initial maternal mortality is higher for countries with high initial lagged GDP per capita and detrended GDP at all lags, relative to those with low lagged initial values of these variables. The the rise in fertility occurs sooner, lasts longer and is more sizable for initially high GDP countries, at all lags, for both detrended GDP and GDP per capita. Initially low GDP per capita countries experience a smaller rise in fertility in comparison, especially for the 10 year lag. The initially low detrended GDP countries seem to display particularly low fertility at t^* for a one year lag, and display a more sizable fertility response than countries with low initial detrended GDP at other lags. While low initial GDP countries begin to experience a sizable bust $25-27$ years after t^*, initially high GDP countries only begin to experience a more moderate decline in fertility at t^*+32.

We also consider the change in detrended GDP and GDP per capita between t^*-1 and t^*-5 and between t^*-1 and t^*-10. A high value of the change in GDP characterizes countries that have experienced an output expansion prior to the decline in maternal mortality, while a low value of this variable characterizes countries that have experienced an output contraction. We consider both GDP and GDP per capita to factor out the impact of demographic factors. As can be seen from the bottom panel, countries with small initial GDP change exhibit higher initial maternal mortality and experience a larger and more protracted rise in fertility, reaching over 40% at the peak, than countries with initially high GDP change. Countries with initially large GDP change between -1 and -5 years exhibit a particularly sharp fertility bust starting at t^*+20, whereas the decline in fertility occurs later and more gradually for countries with initially high GDP change between -1 and -10 years.

Easterlin's (1961) relative income hypothesis predicts that baby booms should occur for cohorts whose income is greater than previous generations, that is countries with positive values of the change in detrended or actual GDP. Jones and Schoonbroodt (2010) present a fertility model in which births are pro-cyclical, consistent with Easterlin's hypothesis, and argue that this can explain low fertility during the Great Depression and the subsequent baby booms in advanced economies. Our analysis suggests that countries with initially high values of GDP and GDP per capita, and initially small values of the change in detrended GDP and GDP per capita exhibit a larger rise in fertility following a decline in maternal mortality, which is consistent, based on the model in Section 2, with the fact that they display high initial maternal mortality.

[14] Detrended GDP is the deviation from a linear trend which is estimated on a country by country basis.

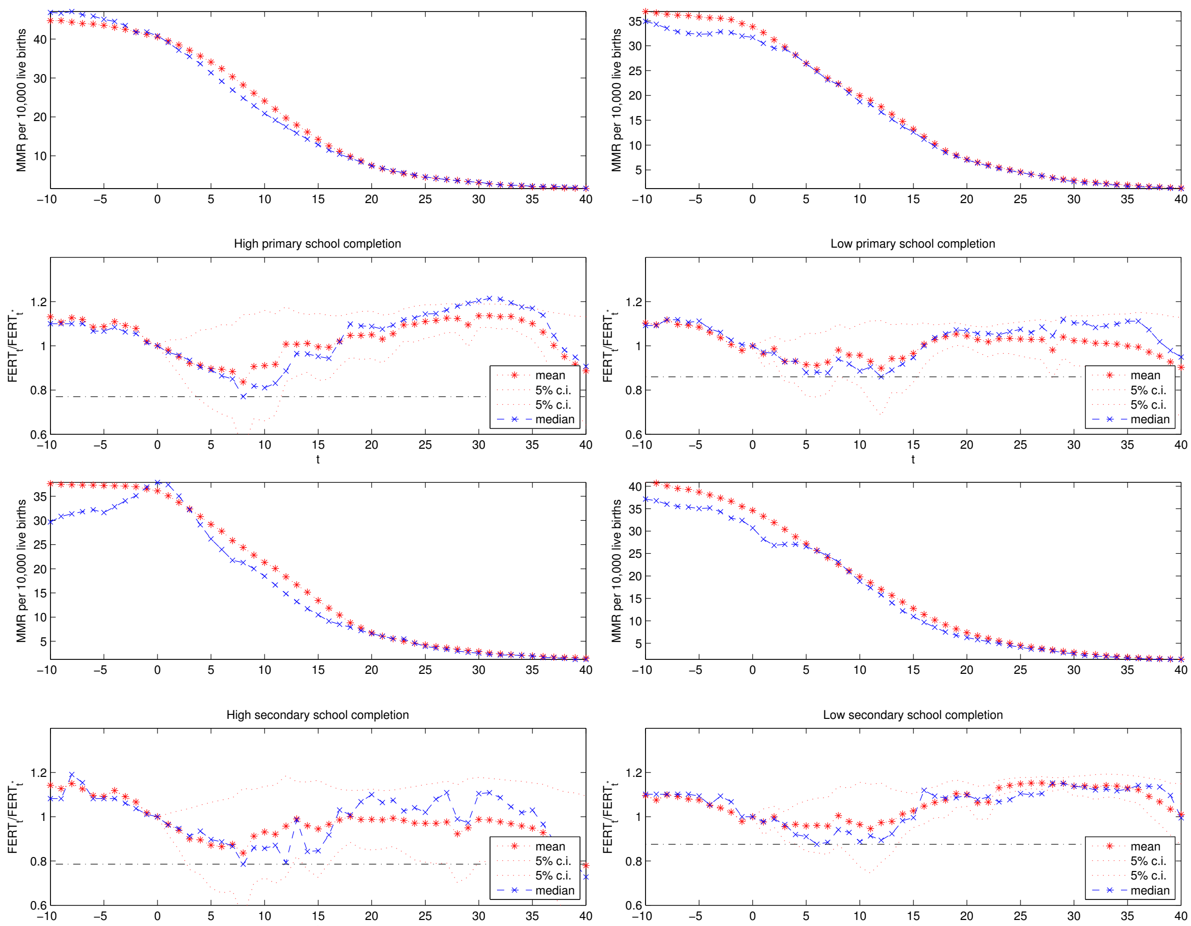
FIGURE 8: Fertility Response to the Maternal Mortality Decline, by Economic Conditions



Sources: GDP per capita from Maddison (2007)

We continue by examining the impact of initial educational attainment, as measured by the fraction of the population which has complete primary and secondary schooling. Once again we divide the countries into two groups, based on whether educational attainment was above and below the median for each measure. The behavior of maternal mortality and fertility in the event window for this exercise is displayed in figure 9. Countries with high initial primary schooling and low initial primary schooling display a stronger response of fertility to the maternal mortality decline. These countries also exhibit higher rates of initial maternal mortality as can be seen from the charts.

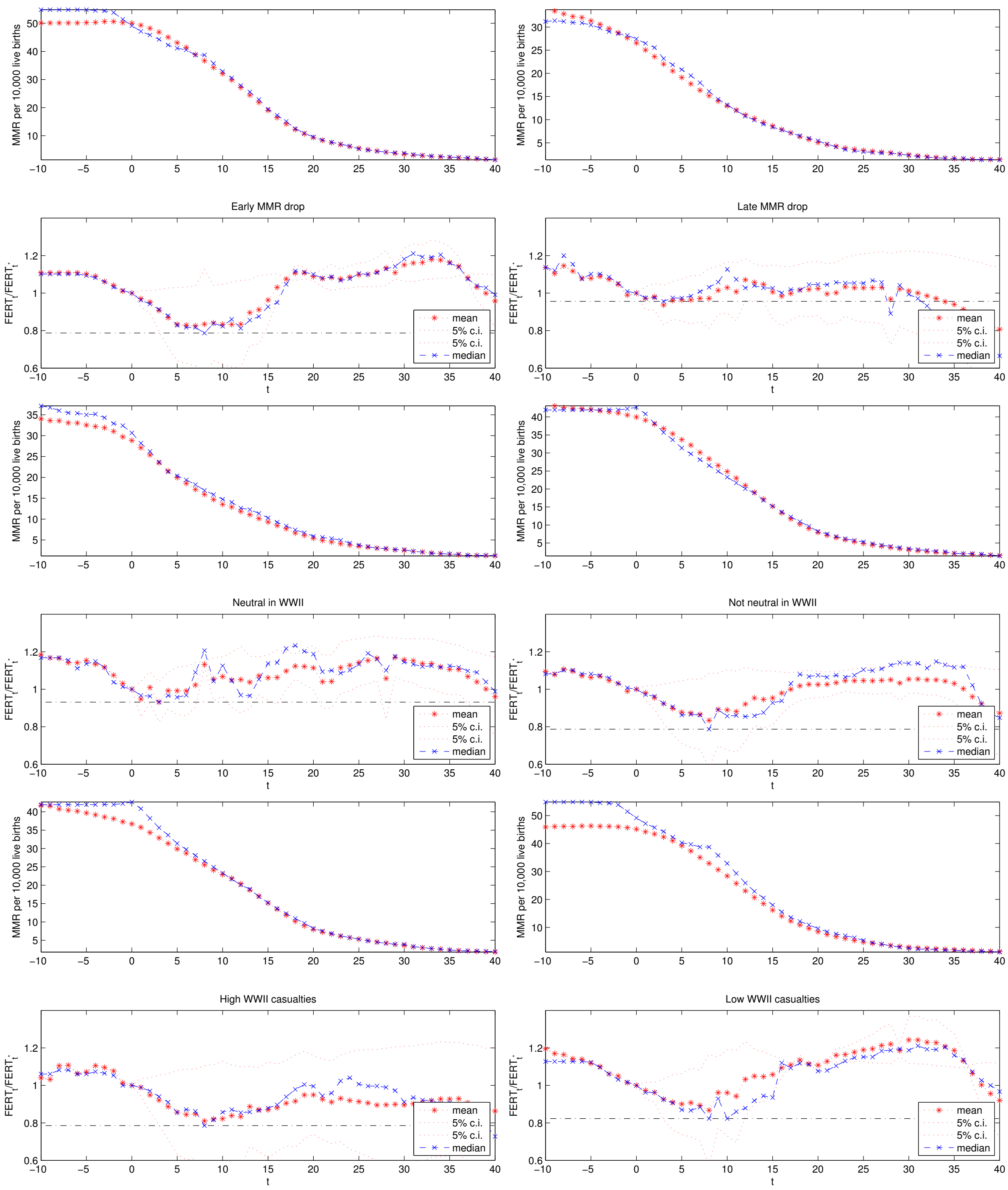
FIGURE 9: Fertility Response to the Maternal Mortality Decline, by Initial Education



Sources: Primary and secondary school completion from Mitchell (2008).

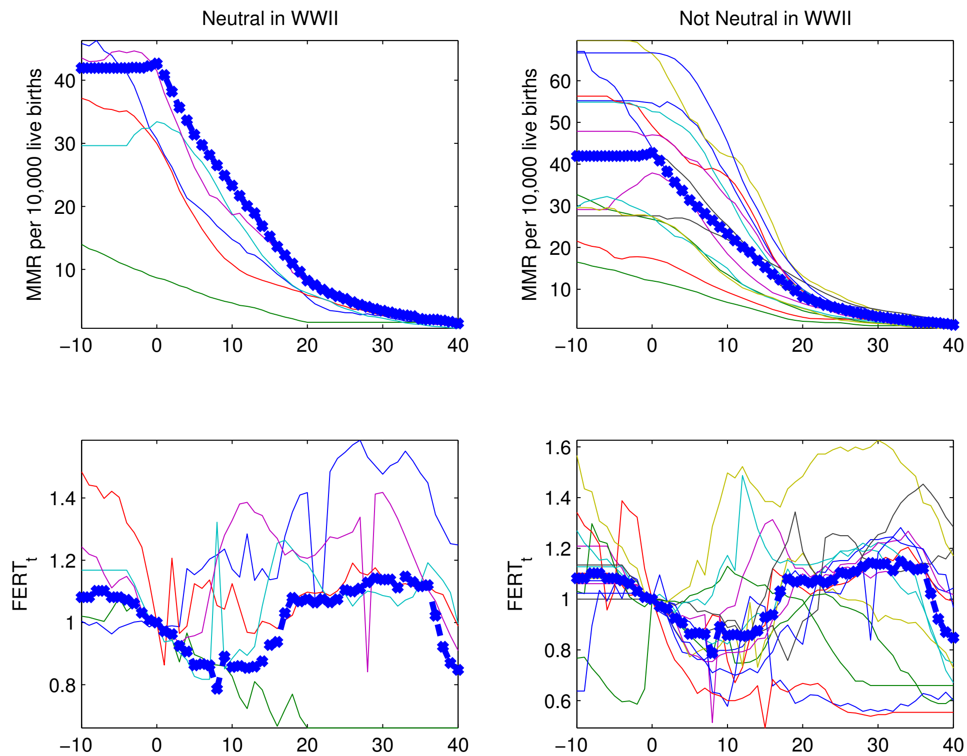
As a final exercise, we check for time effects. First, we separate the countries in the sample based on whether t^* is below (Early MMR drop) or above (Late MMR drop) the median. The countries that experience the drop in MMR early also have higher initial maternal mortality than countries who experience the maternal mortality drop after 1940. We then examine the role of World War II, as the timing of the maternal mortality decline relative to the war may have affected the response of fertility. We first examine the behavior of fertility and of maternal mortality separately for countries that were neutral in the war and countries that participated. As can be see from the chart, countries that participated in the war display larger booms and busts in the fertility window, though they also have higher initial maternal mortality rates. However, as can seen in figure 11, both neutral and non-neutral countries display a variety of fertility responses. This finding goes counter the results in Doepke, Hazan and Mahoz (2007) according which WWII caused the baby boom by discouraging the participation of young women after the war. While war participation per se does not seem to have an independent effect on fertility, the amount of destruction during the war does. We proxy this with the number of casualties as a percentage of the population for non-neutral countries. As can be seen in figure 10, countries with low casualties display very strong baby booms and busts, while fertility declines in countries with high numbers of war casualties as a fraction of the population, despite the fact that initial maternal mortality is slightly higher in the latter group.

FIGURE 10: Fertility Response to the Maternal Mortality Decline, by Impact of World War II



Sources: MMR (maternal deaths per 10,000 live births) Loudon (1992), UN Demographic Yearbook (Various issues), Meigs (1917). TFR from Chesnais (1991).

FIGURE 11: Fertility behavior of individual countries and neutrality in WWII



The event study analysis for fertility confirms the main predictions of the model. The analysis will be replicated with measures of gender differentials in educational attainment.

3.2.1 Regression Analysis

We now estimate the effect of the maternal mortality decline on fertility in the event data for the advanced economies. We use the following regression equation:

$$FERT_{c,t} = \alpha + \beta Z_{c,t}^{MMR} + \gamma IMR_{c,t} + \xi LE_{c,t}^{M} + \chi X_{c,t} + \delta_t + \eta_c + \varepsilon_{c,t}, \tag{6}$$

where $FERT_{c,t}$ denotes a measure of fertility in country c at year t in the event window, $Z_{c,t}^{MMR}$ is a measure of maternal mortality, or an instrument for its decline in the event window, $IMR_{c,t}$ is infant mortality, $LE_{c,t}^{M}$ is male life expectancy at birth, and $X_{c,t}$ is a vector of controls. In addition, we include time and country effects.

The estimated regression coefficients are displayed in Table 3. The baseline specification uses the total fertility rate, we report results for the detrended crude birth rate in Appendix E. The top panel of Table 3reports that baseline estimation results (columns 2), with $Z_{c,t}^{MMR} = MMR_{c,t}$ and controls for contemporaneous GDP per capita and detrended GDP, the proportion of output from industry, completion of primary and secondary schooling, neutrality in World War II and deaths in World War II as a fraction of the population.[15] Column 1 reports the estimates for the same equation when maternal mortality is omitted from the regressors.

The estimates suggest that maternal mortality is inversely related to fertility in the event window. A decline in median maternal mortality of 40 deaths per 10,000 live births is associated with a rise in the total fertility rate of 0.24 children. Infant mortality is also negatively associated with fertility within the event window, though the magnitude of the coefficient is much smaller. Male life expectancy is significantly positively related to fertility in the event window, while detrended GDP, the proportion of output from industry, secondary education and World War II casualties are negatively related to fertility. Column 4 also controls for initial conditions, that is GDP per capita, detrended GDP, the proportion of output in industry, primary and secondary education at t^*. Adding these additional controls confirms the negative relation between maternal mortality and fertility in the event window, both in terms of the magnitude and significance of the effect. Initial GDP per capital, primary and secondary education are significantly negatively related to fertility. Column 3 runs the same specification omitting maternal mortality from the set of regressors. Columns 5 and 6 set $Z_{c,t}^{MMR} = MMR_{c,t-5}$ and $Z_{c,t}^{MMR} = MMR_{c,t-10}$, respectively. Using lagged maternal mortality increases the estimated value of the coefficient on maternal mortality in the regression, and confirms the previous findings.

The bottom panel of Table 3 presents the estimates from an IV specification, with $Z_{c,t}^{MMR} = MMR_{c,t^*} * I_t^{post}$, where I_t^{post} is equal to 1 for $t > \tilde{t}$, where $\tilde{t} > t^*$ and 0 otherwise. Thus, $Z_{c,t}^{MMR}$ is an instrument for the magnitude of the maternal mortality decline in the event window and should be positively associated with fertility for years following t^*. Based on the findings from the graphical analysis in Section 3.2, we consider three values of $\tilde{t}$, equal to 15, 25 and 35 years. The first should capture the initial impact on fertility, the second the peak impact, while the the third value is intended to detect a decline in fertility. Columns 1-3 in the bottom panel present the baseline results. The estimated coefficient for $Z_{c,t}^{MMR}$ is highly significant for all values of $\tilde{t}$ and suggests a relation consistent with the theory. A decline in maternal mortality of 40 deaths per 10,000 live births is associated with a rise in the total fertility rate of 0.112 children $\tilde{t} = 15$, of 0.12 children at $\tilde{t} = 25$ and of 0 children at $\tilde{t} = 35$, suggesting a boom-bust pattern. Columns 4-6 present results for a specification which also controls for initial conditions interacted with $Z_{c,t}^{MMR}$. This specification isolates the effects of the initial conditions on the fertility response to the mortality decline at $\tilde{t}$. Controlling for initial conditions in this fashion increases the magnitude of the estimated coefficient on $Z_{c,t}^{MMR}$ for $\tilde{t} = 15$, 25, suggesting that a decline in maternal mortality of 40

[15]Given that the World War II controls are time invariant, country effects are excluded.

deaths per 10,000 live births is associated with a rise in the total fertility rate of 0.16 and and 0.14 children, respectively. The coefficient at $\tilde{t} = 35$ is now negative and significant, though small in value, confirming the boom-bust response of fertility. The initial conditions that are significantly related to the fertility response are male life expectancy, which tends to increase the magnitude of the fertility response at all values of $\tilde{t}$, and secondary education, which tends to reduce the size of the fertility increase.

TABLE 3: Advanced Economies: Regression Results

Specification[1]						Panel						
Dependent Variariable						**Total Fertility Rate**						
	Coefficient	**t-stat**	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**
Constant	7.4893	7.0066	16.1303	11.3112	13.0096	8.2103	18.5721	10.7313	20.0756	12.2708	18.6654	11.7044
MMR_t			**-0.0061**	**-8.769**			**-0.0052**	**-7.1574**				
MMR_{t-5}									**-0.0071**	**-10.8236**		
MMR_{t-10}											**-0.0067**	-10.6167
IMR_t	-0.0012	-6.5489	-0.0009	-4.9307	-0.0008	-4.34	-0.0006	-3.4499	-0.0002	-1.3261	-0.0001	-0.3965
Male life expectancy at age 0	0.0025	4.733	0.0029	5.8103	0.0033	5.592	0.0035	5.9212	0.0038	6.7639	0.004	7.0575
GDP per capita	0.0101	2.6713	0.0044	1.1956	0.0306	5.881	0.0183	3.4181	0.0138	2.6737	0.0153	2.976
Detrended GDP	-0.0617	-11.0762	-0.0346	-5.5761	-0.075	-11.9345	-0.0469	-6.4448	-0.0422	-6.3165	-0.0514	-8.0756
Proportion of output in industry	-0.0026	-6.0345	-0.003	-7.0989	-0.0024	-3.7319	-0.0026	-4.2028	-0.0026	-4.3838	-0.0024	-3.9993
Primary education	-0.3194	-1.7005	0.0289	0.1558	0.222	0.7182	0.4629	1.5254	0.0967	0.3302	-0.3819	-1.2787
Secondary education	-2.5112	-6.9509	-1.9894	-5.6285	-1.0287	-1.9629	-0.653	-1.2702	-0.7024	-1.4131	-1.0416	-2.0952
GDP per capita at t*					-0.0463	-4.8943	-0.0253	-2.6095	-0.0141	-1.4995	-0.0133	-1.4055
Detrended GDP at t*					0.0217	2.2583	0.0117	1.233	0.017	1.8671	0.0271	2.9688
Proportion of output in industry at t*					-0.0009	-1.5437	-0.0009	-1.5599	-0.0012	-2.1324	-0.0015	-2.7729
Primary education at t*					-0.8795	-2.4792	-0.785	-2.266	-0.1766	-0.5163	0.3728	1.0454
Secondary educaton at t*					-1.3596	-1.6047	-1.7026	-2.0558	-1.7835	-2.2208	-1.6419	-2.0418
WWII neutrality	0.0562	2.9932	0.0526	2.906	0.0272	1.3958	0.036	1.8885	0.0527	2.8318	0.0651	3.4574
WWII casualties	-2.4074	-2.197	-0.9837	-0.9201	-3.902	-2.7902	-1.1782	-0.8316	1.6404	1.1556	3.0513	2.0625
Country effects												
R squared	0.338		0.3843		0.373		0.4028		0.438		0.4358	
Adj R squared	0.3445		0.391		0.3822		0.4122		0.4468		0.4446	
p-value	0		0		0		0		0		0	

Specification (1)						IV						
Dependent Variariable						**Total Fertility Rate**						
	Coefficient	**t-stat**	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**
Constant	13.7291	8.7898	12.7783	8.2195	13.0145	8.2012	13.226	8.7345	12.7933	8.3479	12.7924	8.0836
$MMR_{t*} x I_t^{post}$												
t*+15	**0.0028**	6.0282					**0.004**	7.3832				
t*+25			**0.003**	6.3706					**0.0034**	5.7813		
t*+35					**0**	-0.0707					**-0.0004**	-0.5261
IMR_t	-0.0008	-4.1236	-0.0008	-4.2805	-0.0008	-4.3266	-0.0014	-7.117	-0.0011	-5.6512	-0.0009	-4.5423
Male life expectancy at age 0	0.0035	6.0222	0.0038	6.4865	0.0033	5.573	-0.0009	-1.1952	0.002	3.0012	0.0031	4.8837
GDP per capita	0.0165	2.9392	0.0141	2.4546	0.0307	5.6048	0.0101	1.8067	0.0122	2.0964	0.0318	5.7532
Detrended GDP	-0.0554	-7.9448	-0.0598	-9.0546	-0.075	-11.8596	-0.0516	-7.4891	-0.0579	-8.8419	-0.072	-11.2969
Proportion of output in industry	-0.0028	-4.5536	-0.0024	-3.9545	-0.0024	-3.7307	-0.0022	-3.3879	-0.0021	-3.2968	-0.002	-3.133
Primary education	0.2649	0.8719	-0.4557	-1.4184	0.2265	0.7172	0.5378	1.7613	-0.5004	-1.4394	0.7419	2.1839
Secondary education	-1.1997	-2.3257	-1.6788	-3.2035	-1.0229	-1.9276	-0.6337	-1.2479	-1.34	-2.5168	-1.3231	-2.4312
GDP per capita at t*	-0.0388	-4.134	-0.0344	-3.6317	-0.0464	-4.8401	-0.0468	-4.6329	-0.0411	-4.115	-0.0519	-5.3459
Detrended GDP at t*	-0.0007	-0.0738	0.0073	0.7563	0.0218	2.2501	-0.0102	-1.0101	0.0063	0.6542	0.0204	2.0991
Proportion of output in industry at t*	-0.0002	-0.434	-0.0006	-1.0844	-0.0009	-1.5436	-0.0007	-1.0689	-0.0005	-0.8618	-0.0011	-1.8532
Primary education at t*	-1.194	-3.387	-0.4357	-1.2279	-0.8828	-2.4659	-1.4956	-3.977	-0.4985	-1.3419	-1.2673	-3.4197
Secondary educaton at t*	-0.698	-0.8311	-0.4662	-0.5532	-1.3664	-1.6017	-0.6369	-0.701	-0.4297	-0.485	-1.0172	-1.163
WWII neutrality	0.0119	0.6141	0.0232	1.2106	0.0272	1.3936	0.0078	0.4279	0.0209	1.124	0.0233	1.1993
WWII casualties	-6.2994	-4.4025	-4.8895	-3.542	-3.8997	-2.7864	-7.225	-5.1075	-5.3878	-3.9227	-4.4547	-3.1716
IMR_{t*}^{ind} X MMR_{t*} X I^{post}_t (2)							0	-1.1378	0	-1.8024	0	-3.8168
Male Life Expectancy$_{t*}^{ind}$ X MMR_{t*} X I^{post}_t (2)							**0.0002**	6.2085	**0.0001**	3.3858	**-0.0001**	-2.2119
GDP per capita$_{t*}^{ind}$ X MMR_{t*} X I^{post}_t (2)							0.0006	1.935	0.0003	1.0048	0.0009	1.8875
Proportion of Output in Industry$_{t*}^{ind}$ X MMR_{t*} X I^{post}_t (2)							0	0.176	0	-1.7908	0	-0.4884
Primary education$_{t*}^{ind}$ X MMR_{t*} X I^{post}_t (2)							-0.0069	-0.7851	0.004	0.4068	-0.0168	-1.1547
Secondary education$_{t*}^{ind}$ X MMR_{t*} X I^{post}_t (2)							**-0.0799**	-3.274	**-0.0716**	-2.6487	-0.0372	-0.945
R squared	0.3943		0.3968		0.3724		0.4652		0.4356		0.382	
Adj R squared	0.4038		0.4062		0.3822		0.4768		0.4478		0.3954	
p-value	0		0		0		0		0		0	

Notes

1 All specifications include time effects.

2 For each variable x, x_{t*}^{ind}=sign((x_{t*}-median(x_{t*}))). Thus, each indicator is equal to 1for countries with a value greater than the median at t*.

These estimates suggest a strong empirical relation between maternal and infant mortality and fertility, which is consistent with the predictions of the model. However, this approach can only capture the direct relation between maternal mortality and fertility, and not the more subtle indirect linkage that runs through the response of female human capital in the theory. Since a key determinant of the returns to human capital is the length of the productive life span, we examine the impact of the maternal mortality decline on the female-male differential in life expectancy in the event window. The results are displayed in Table 4. The specification is the same as in equation (7), except here the female-male differential in life expectancy at age 0 is the dependent variable. We estimate a panel and an IV specification. In the panel specification, we find that the gender differential in life expectancy is significantly positively related to maternal mortality in the event window. A rise in maternal mortality of 40 deaths per 10 ,000 live births is associated with a rise in the gender differential in life expectancy of 1.2 years. The same finding emerges when maternal mortality is lagged by 5 and 10 years. This finding is surprising in light of the graphical analysis displayed in figure 4.

We also estimate an instrumental variables specification, following the same approach as for fertility. Here, we would expect a positive coefficient on the instrument for initial maternal mortality, if a decline in maternal mortality is associated with a subsequent rise in the female-male differential in life expectancy. The estimates are consistent with this effect, and suggest that a decline in maternal mortality by 40 deaths per 10,000 live births is associated with a rise in the female-male differential in life expectancy by 0.40 years at $t^* + 25$ and 0.60 years at $t^* + 35$.

All the controls, except for neutrality in World War II, display highly significant coefficients. In all specifications, male life expectancy at age 0, GDP per capita, the proportion of output in industry and World War II casualties as a fraction of the population are positively related to the gender differential in life expectancy, while detrended GDP, primary and secondary education are negatively related to the differential.

Table 4: Advanced Economies: Impact on Life expectancy

Specification (1)	**Panel and IV**													
Dependent Variariable	**Female-Male Differential in Life expectancy**													
	Coefficient	**t-stat**	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**	**Coefficient**	**t-stat**
Constant	-74.0479	-7.3812	-120.1267	-8.8025	-119.849	-8.964	-115.7744	-8.9529	-72.3067	-7.1877	-70.1411	-6.9276	-70.699	-7.0366
MMR_t			**0.0323**	**4.916**										
MMR_{t-5}					**0.03**	**5.1031**								
MMR_{t-10}							**0.027**	**5.0253**						
$MMR_{t*} x I_t^{post}$														
t*+15									0.0068	1.9173				
t*+25											**0.0097**	**2.5201**		
t*+35													**0.015**	**3.1055**
Male life expectancy at age 0	0.0539	11.5539	0.0527	11.4288	0.0543	11.7868	0.0558	12.0645	0.0563	11.6605	0.0569	11.8472	0.0563	11.9556
GDP per capita	0.0636	1.8889	0.105	3.0584	0.0943	2.7884	0.0785	2.35	0.0271	0.6998	0.0242	0.6539	0.0351	1.0096
Detrended GDP	-0.0865	-1.6541	-0.2284	-3.8575	-0.179	-3.2698	-0.1252	-2.3964	-0.0382	-0.6581	-0.0508	-0.9404	-0.0818	-1.5716
Proportion of output in industry	0.0125	3.1049	0.0146	3.6556	0.0154	3.8261	0.0155	3.8489	0.0118	2.9289	0.0118	2.9301	0.0122	3.0482
Primary education	-2.6348	-1.5073	-4.2509	-2.4162	-3.9193	-2.246	-3.5725	-2.0561	-3.4312	-1.9121	-4.1779	-2.261	-3.7183	-2.0945
Secondary education	-23.0177	-6.7927	-25.6157	-7.5523	-24.4609	-7.2816	-23.0241	-6.8757	-21.6744	-6.2718	-22.2802	-6.5679	-22.8041	-6.757
WWII neutrality	0.0983	0.559	0.1307	0.7513	0.1224	0.7043	0.1078	0.6207	0.0661	0.3746	0.0553	0.3137	0.0771	0.4399
WWII casualties	94.4571	9.3275	88.6743	8.7958	86.7187	8.5709	84.8743	8.3313	91.1594	8.8862	91.8641	9.0486	93.3286	9.2494
R squared	0.3508		0.3653		0.3665		0.366		0.3525		0.3542		0.3563	
Adj R squared	0.3565		0.3715		0.3727		0.3722		0.3588		0.3605		0.3626	
p-value	0		0		0		0		0		0		0	

Notes
1 All specifications include time effects.

3.3 Sweden: A Case Study

We now focus on Sweden for which a comprehensive set of reliable demographic data, as well as data on maternal mortality, are available starting in 1800. As can be seen in Figure 12, Sweden displays three episodes of sharp maternal mortality reduction in 1808, 1872 and 1932. By contrast, infant mortality declines gradually at a close to constant rate for the entire time period. A sharp rise in fertility occurs following the 1808 and 1932 episodes of maternal mortality reduction, followed by a sharp decline. Between 1808 and 1928, the total fertility rate rises from 3 to 5 children, and then drops to just under 4 children by 1837, when it starts rising again. Fertility rises from 1.7 to 2.6 children between 1933 and 1945, and remains at approximately 2.5 children until 1962, when it drops sharply, reaching 1.6 children in the late 1970s. The 1872 episode displays a different pattern. Maternal mortality rises sharply between 1860 and 1872, from 45 to 64 deaths per 10,000 live births, before dropping to 22 deaths per 10,000 live births by 1884.[16] The rise in maternal mortality that preceded the 1872 episode is accompanied by a drop in the total fertility rate of approximately 0.5 children. Fertility rises again between 1866 and 1973, before entering a protracted period of decline, which takes the total fertility from 4.5 in 1873 to the trough of 1.7 in 1933.

[16] Maternal mortality also rises prior to the 1932 episode, though most of this rise is due to the influenza pandemic of 1918, as well as improved measurement (Loudon, 1992).

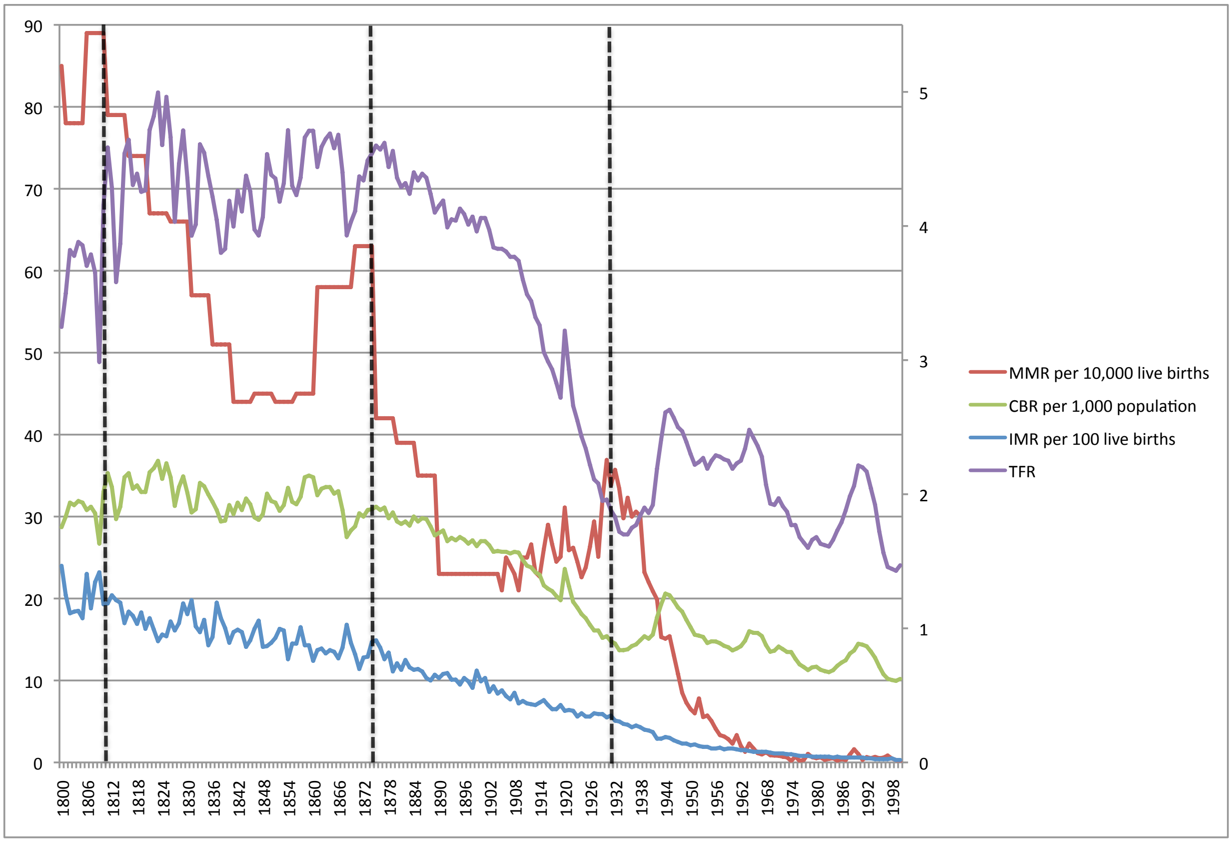


FIGURE 12: Maternal mortality, infant mortality and fertility in Sweden

Figure 13 isolates the behavior of fertility and maternal mortality and additional economic and health indicators in a $\{-10, +30\}$ year window around the episodes of maternal mortality reduction. The figure highlights the differences between the 1808 and 1932 episodes and the 1872 episode. The 1808 and 1932 episodes are characterized by a rise in fertility of over 45%, and a rise in the female-male differential in life expectancy of approximately 3 years. By contrast, fertility briefly rises prior to 1872, recovering from a temporary dip in the 1860s, and then falls by 20%, while the female-male differential in life expectancy falls throughout the event window for the 1872 episode, despite the continued rise in male life expectancy during the event window. The 1872 episode is also notable for being preceded by a sharp decline in GDP per capita, due to a famine that occurred in the 5 years preceding the episode.

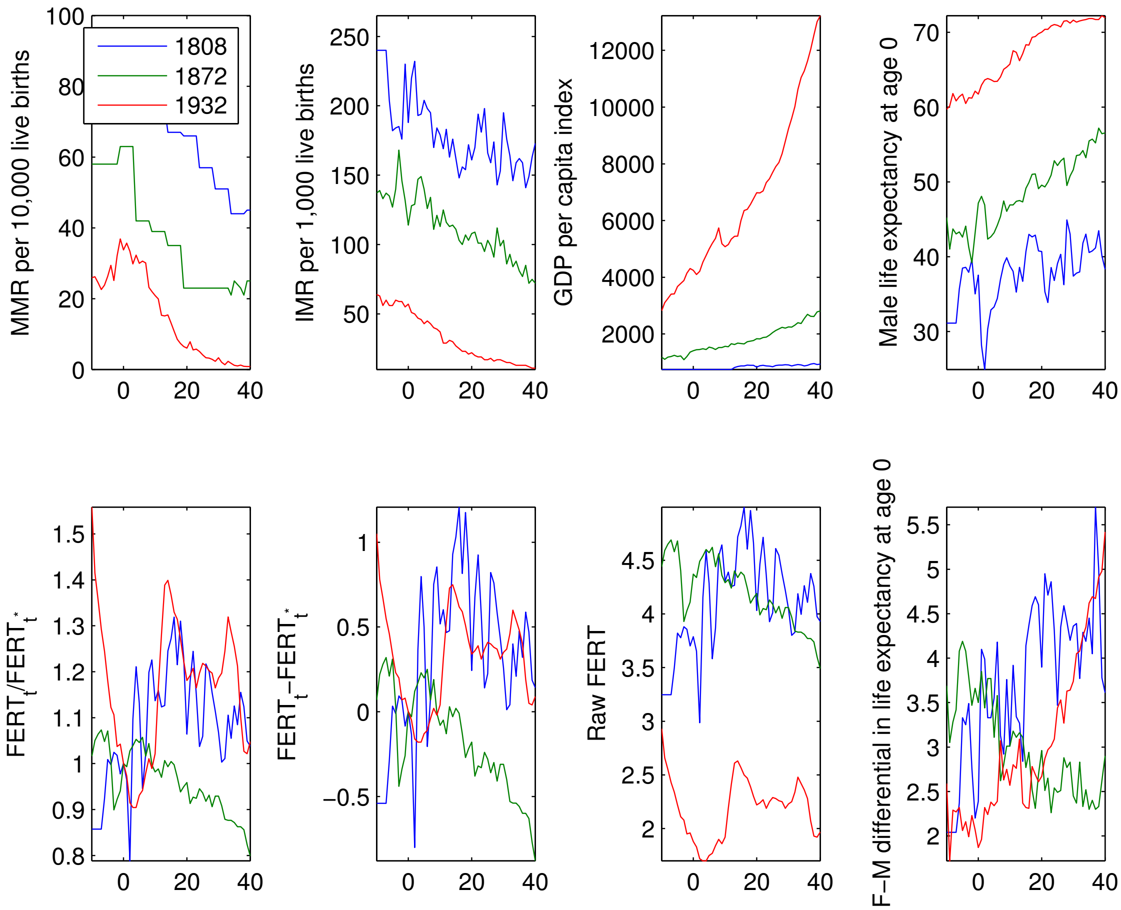


FIGURE 13: Health and economic indicators during episodes of maternal mortality reduction in Sweden

Figure 14 plots the median and mean response of fertility, measured by the TFR, during the event window, confirming the descriptive evidence discussed above. Fertility rises significantly between $t^* + 6$ and $t^* + 20$ after the event, peaking at $t^* + 16$ at $+35\%$, and converges back to pre-event levels by $t^* + 30$.

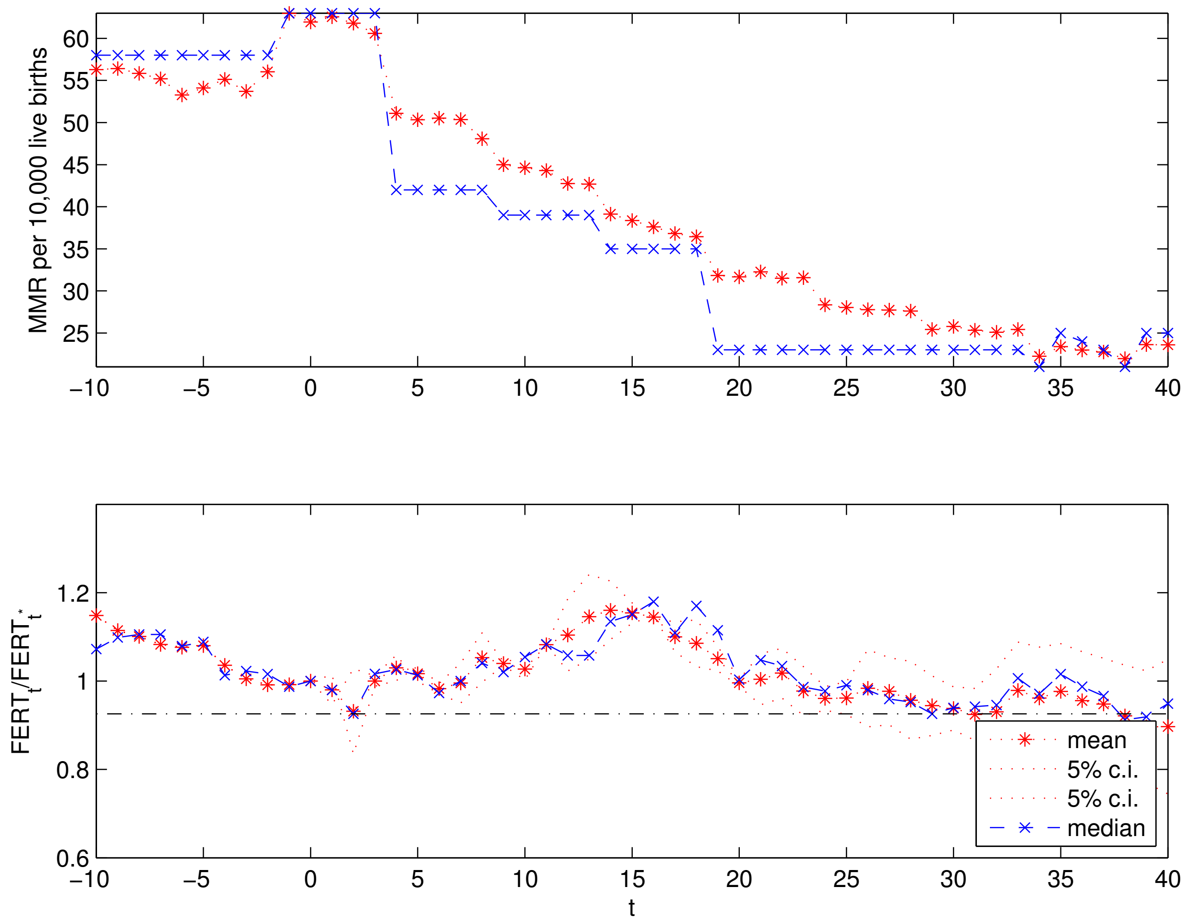


FIGURE 14: Fertility response to episodes of maternal mortality decline, Sweden

To conclude, the behavior of fertility in response to episodes of sharp maternal mortality declines in Sweden is consistent with the theory for the 1808 and the 1932 episodes. The 1872 episode displays some peculiarities, probably due to the fact that the decline in maternal mortality followed a period of sharp increase in this variable (and a sharp drop in fertility), associated with adverse economic conditions in the late 1860s, which were also accompanied by a temporary drop in fertility, a rise in infant mortality and a decline in male life expectancy. It remains an open question why other health indicators recovered, while the female-male differential in life expectancy continued to fall after the 1872, even as maternal mortality was declining.

3.4 Emerging Economies

We now examine the response of fertility to a maternal mortality reduction in Argentina, Chile, Mexico and Peru, the only emerging economies for which maternal mortality data is available starting in the 1920s. Figure 15 plots maternal mortality, infant mortality and the crude birth rate in these countries in 1900-2000. Infant mortality and the crude birth rate are much higher than in most advanced economies in the 1930s, with infant mortality in 1935 ranging from 106 deaths per 1,000 live births in Argentina, which has the lowest rate, to 2151 in Chile which has the highest rate, and the crude birth rate ranging between 25 births per 1,000 population in Argentina to 42.3 births per 1,000 population in Mexico in the same year. Maternal mortality in Argentina, at 398 deaths per 100,000 live births in 1934, is comparable to the values observed in Northern European countries, while it is much higher in the remaining countries in the same year, with Chile at 911 deaths per 100,000 live births, Mexico at 617 deaths and Peru at 672 deaths.

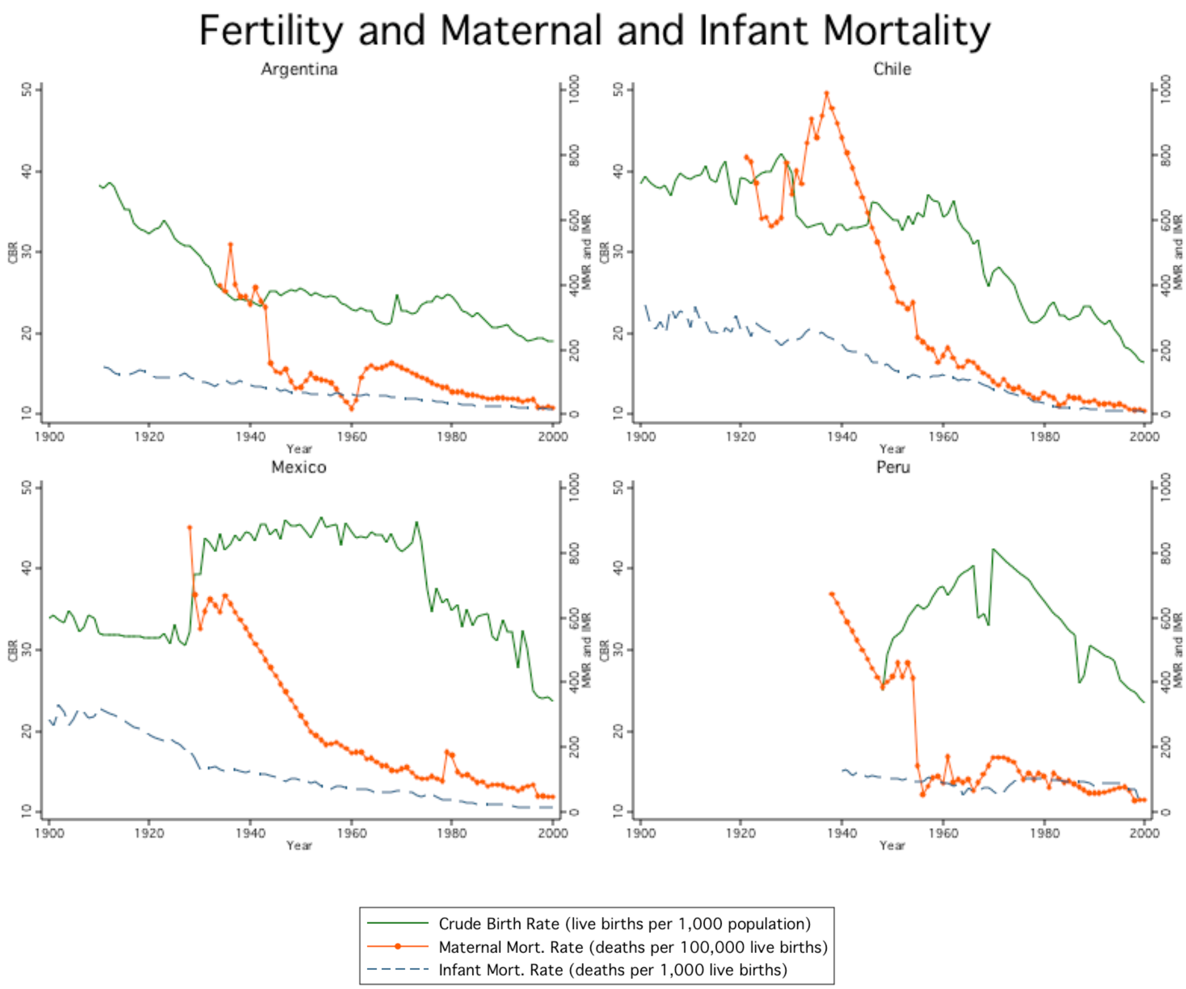


Figure 15: Maternal Mortality, Infant Mortality and Fertility 1900-2000

All countries in this group experience multiple episodes of sharp mortality decline, defined, for this sample, as a decline in maternal mortality by at least 50% in 10 years. The dating of the episodes and the initial values of maternal and infant mortality and fertility is reported in Table 5. Argentina experiences two events in 1936 and 1968, Chile experiences two events in 1921 and 1937, Mexico in 1927 and 1979, and Peru in 1938 and 1970. Initial maternal mortality is very high for the early events, occurring in the 1920s and 1930s. Infant mortality and the crude birth rate are also very high at the start of these early events, compared to the advanced economies. Argentina stands out as the country in which maternal and infant mortality and fertility at the start of the episodes of maternal mortality reduction is most similar to the values displayed by advanced economies in the same years.

Table 5: Episodes of maternal mortality reduction

Country	Year	Initial MMR per 10,000 live births	Initial IMR per 1,000 live births	Initial CBR
Argentina	1936	53	97	25
	1968	15	55	21
Chile	1921	79	278	39
	1937	99	241	32
Mexico	1927	88	193	31
	1979	19	39	36
Peru	1938	67	128	25
	1970	17	65	42

We conduct an event study analysis following the same approach as in advanced economies. The behavior of fertility, measured by the crude birth rate and its deviation from trend are displayed in figure 16. We choose a narrow event window, due to the occurrence of multiple events in each country. As can be seen from the figure, the decline in maternal mortality is more gradual for these events, than observed for advanced economies. The response of the crude birth rate is significantly positive in years $6-14$ following t^*, but fertility rises by less than 10% at the peak and trends downwards throughout the event window. The detrended crude birth rate displays a much larger and more protracted response, starting out at trend in t^*, peaking after 12 years. A decline in the detrended CBR starts at the very end of the event window, 25 years after t^*.

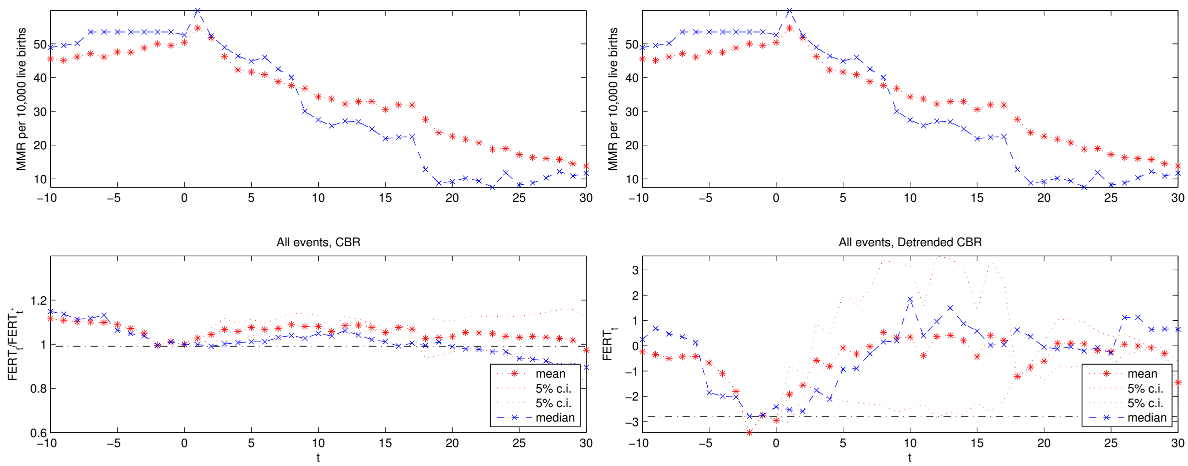


FIGURE 16: Argentina, Chile, Mexico, Peru 1920-2000: Fertility Response

Given that all countries experience the events in two different time periods, the first in the late 1920s and 1930s and the second in 1960s or 1970s, we examine the response of fertility separately for these two groups of events. As shown in figure 17, early events, which display much higher initial mortality rate, exhibit a sizable and prolonged response of fertility. By contrast, for late events fertility starts rising at t^* and peaks 10 years later, before experiencing a pronounced decline. Early events are characterized by higher initial infant mortality and fertility, than later events, which should partly offset the response of fertility according to the theory, though the high initial maternal mortality seems to dominate in the empirical response.

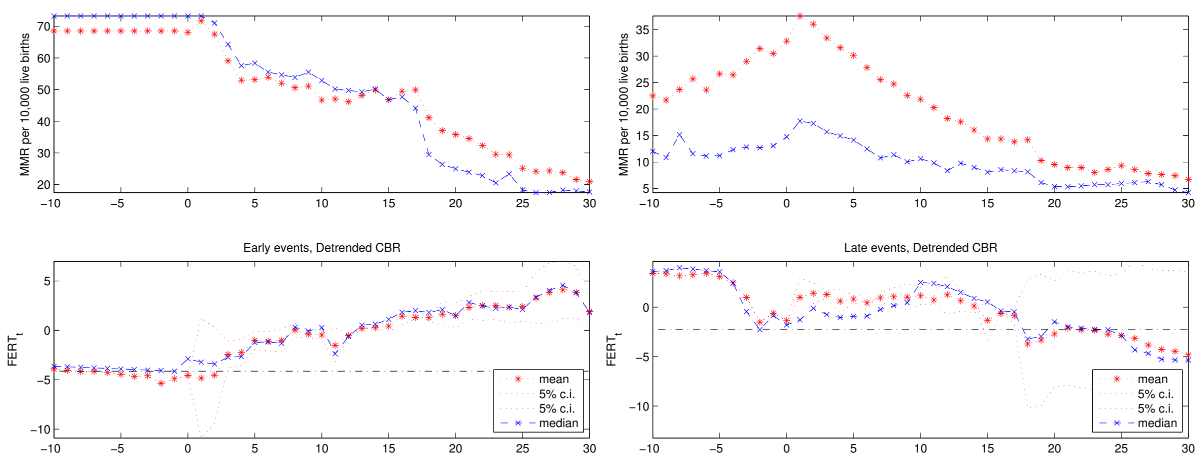


FIGURE 17: Argentina, Chile, Mexico, Peru 1920-2000: Fertility Response by Timing

The response of fertility for late events suggests joint endogeneity, as fertility starts rising contemporaneously to maternal mortality decline. To assess this hypothesis, we examine the response of fertility based on the value of detrended GDP. As can be seen in figure 18, events characterized by high initial detrended GDP (Chile 1937, Mexico 1927 and both Peruvian events) exhibit a sizable response of fertility, which starts to rise at t^*, whereas countries with low initial detrended GDP display a more muted response. Whereas for events with initially low detrended GDP, there is a sizable rise in fertility $t^* + 5$ followed by a protracted decline. This finding may be due to the fact that the timing of births is sensitive to economic conditions, and high values of detrended GDP are associate with both a reduction in maternal mortality and a rise in fertility.[17]

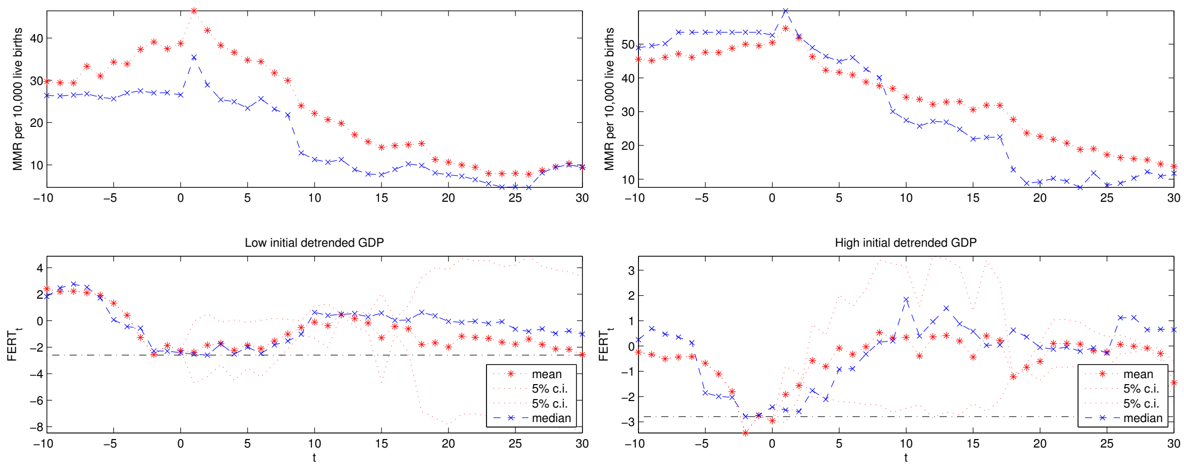


FIGURE 18: Argentina, Chile, Mexico, Peru 1920-2000: Fertility Response by Timing

3.5 Effects on Education

A key prediction of the model is that the decline in maternal mortality should lead to a rise in women's human capital relative to men, and that the corresponding rise in the opportunity cost of children for women should determine a decline in fertility, following the initial boom. The previous sections document that indeed the booms in fertility were followed by substantial busts. We now seek to provide direct evidence on the response of female education.

We use the Barro and Lee (2010) data set on educational attainment, the only harmonized source for education data by gender over a long time period. The data starts in 1950 and is available at 5 year intervals. We examine education for individuals of age 25 and over in the population, in order to capture completed schooling. We estimate the following specification:

$$E_{c,t,g} = \alpha + \beta MMR_{c,\tilde{t}} * I_g + \gamma MMR_{c,\tilde{t}} + \delta X_{c,t} + \eta_t + \varepsilon_{c,t}, \tag{7}$$

[17] Measures of completed fertility, such as the total fertility rate, which are not sensitive to the timing of births, would enable us to examine this hypothesis but they are not available for the entire sample period for these countries.

where $E_{c,t,g}$ denotes educational attainment in country c, at time t, for gender $g = f, m$, $MMR_{c,\tilde{t}}$ is the lagged value of maternal mortality in country c, with $\tilde{t} = t-5, t-10$, $t-15$, $t-20$, I_g is the female dummy, $X_{c,t}$ is a vector of controls, and η_t denotes time effects.

The specification includes both lagged maternal mortality and its value interacted with the female dummy. The model predicts that countries with a larger decline in maternal mortality will experience a greater rise in female educational attainment relative to men. A negative estimated value of β is consistent with this prediction, since:

$$(E_{c,t',f} - E_{c,t',f}) - (E_{c,t',m} - E_{c,t,f}) = \beta \left(MMR_{c,\tilde{t}'} - MMR_{c,\tilde{t}} \right),$$

for $t' > t$. We also include the value of lagged maternal mortality not interacted with the female dummy to capture any independent effects on maternal mortality decline on both female and male education. Given that we are considering a set of mostly advanced economies, we expect the maternal mortality decline to influence secondary and tertiary education completion rates and average years of schooling in the female population, and we consider these three measures as dependent variables.

The results from the estimation are displayed in Table 6. We consider two sets of controls. In the first, we include infant mortality and male life expectancy at age 0, as well as the values of GDP per capita, proportion of output from industry, primary education (in the overall population) and secondary education at t^* (labelled as "initial" in the table). In the second, we include infant mortality and male life expectancy at t^* , in addition to the other initial conditions.

We find that the lagged maternal mortality has a significant negative effect on the growth in female educational attainment relative to men. The estimates for average years of schooling and tertiary school completion are highly significant and suggest a sizable effect. The estimated coefficient implies that average years of schooling for females should rise by $0.20-0.46$ years, depending on the specification, for a decline in maternal mortality of 10 deaths per 10,000 live births. Similarly, for tertiary school completion, the estimates predict that the female completion should rise by $0.9-2.1\%$ for a decline in maternal mortality of 10 deaths per 10,000 live births.

The effects for secondary completion are not significant, though the coefficient on maternal mortality interacted with the female dummy has the right sign. This may be due to the fact that most countries in the analysis had compulsory secondary schooling in the sample period.

Taken together, these results suggest that the maternal mortality decline may have had a positive effect on the female-male differential in educational attainment, as measured by average years of schooling and secondary education, confirming a key mechanism predicted by the theory.

Table 6: Educational Response to the Maternal Mortality Decline

Specification [1,2]	**IV**											
Dependent Variariable	**Female-male difference in Average Years of Schooling**											
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Constant	23.4191	3.3109	25.0239	3.5819	28.1996	3.869	10.5884	2.0844	17.2342	3.2713	20.6015	3.4502
$MMR_{**}xI_t^{post}$												
I_t^{post}=1 for t>1950			**0.0067**	**2.6949**					**0.0089**	**3.5802**		
I_t^{post}=1 for t>t*-2					**0.0056**	**2.3279**					**0.0073**	**3.0323**
IMR	-0.0025	-1.3517	-0.0011	-0.5551	-0.0013	-0.6609						
Male life expectancy at age 0	0.0194	7.188	0.0208	7.6773	0.0206	7.5715						
Initial Infant Mortality							-0.0028	-3.2162	-0.0023	-2.6409	-0.0024	-2.7614
Intial male life expectancy at age 0							0.0147	4.0978	0.0189	5.1357	0.0179	4.874
Initial GDP per capita	-0.0595	-1.6304	-0.0743	-2.0451	-0.0707	-1.9439	-0.1026	-2.567	-0.1306	-3.3005	-0.1232	-3.1017
Initial proportion of output in industry	0.0006	0.2377	0.0005	0.2061	0.0006	0.2366	-0.0012	-0.5047	-0.0008	-0.3564	-0.0009	-0.3561
Initial primary education	6.1095	4.6954	4.9804	3.6967	5.2576	3.931	5.521	4.2642	3.9505	2.9681	4.3406	3.2726
Initial secondary educaton	-6.6021	-3.0921	-5.5443	-2.5938	-5.7159	-2.6647	-8.9378	-3.9982	-7.6537	-3.4804	-7.863	-3.5456
Adj R squared	0.3232		0.3445		0.3384		0.3075		0.3477		0.3359	
R squared	0.347		0.3709		0.365		0.3319		0.3739		0.3626	
p-value	0		0		0		0		0		0	
Dependent Variariable	**Female-male difference in Primary School Completed**											
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Constant	85.5064	1.0503	76.4174	0.9369	65.3677	0.7698	-166.2849	-2.785	-155.0449	-2.4255	-132.7883	-1.8516
$MMR_{**}xI_t^{post}$												
I_t^{post}=1 for t>1950			-0.038	-1.3074					0.0151	0.499		
I_t^{post}=1 for t>t*-2					-0.0235	-0.8417					0.0243	0.8446
IMR	-0.0836	-3.9111	-0.0918	-4.1281	-0.0888	-3.9875						
Male life expectancy at age 0	0.0435	1.3988	0.0359	1.1347	0.0387	1.2225						
Initial Infant Mortality							0.0109	1.0652	0.0118	1.1337	0.0123	1.1849
Intial male life expectancy at age 0							0.1184	2.8005	0.1254	2.8097	0.129	2.923
Initial GDP per capita	0.9351	2.2276	1.0189	2.4037	0.9825	2.3181	1.0247	2.1819	0.9774	2.036	0.9558	2.0035
Initial proportion of output in industry	-0.0109	-0.3968	-0.0105	-0.3803	-0.0109	-0.3951	-0.0132	-0.4602	-0.0126	-0.4361	-0.012	-0.415
Initial primary education	-15.9544	-1.0653	-9.5591	-0.6077	-12.3656	-0.7936	-5.711	-0.3753	-8.3671	-0.5181	-9.6595	-0.6064
Initial secondary educaton	33.6565	1.3695	27.6653	1.1086	29.9232	1.1973	29.5415	1.1243	31.7132	1.1885	33.1367	1.244
Adj R squared	0.1602		0.1633		0.1589		0.104		0.1005		0.1027	
R squared	0.1897		0.1969		0.1927		0.1355		0.1367		0.1387	
p-value	0		0		0		0.0002		0.0004		0.0003	
Dependent Variariable	**Female-male difference in Secondary School Completed**											
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Constant	25.1297	0.4074	42.9019	0.7126	80.6369	1.2829	83.1693	1.9344	125.2309	2.7679	148.4634	2.9094
$MMR_{**}xI_t^{post}$												
I_t^{post}=1 for t>1950			**0.0743**	**3.4631**					**0.0565**	**2.6385**		
I_t^{post}=1 for t>t*-2					**0.0649**	**3.1343**					**0.0473**	**2.3137**
IMR	0.0237	1.4637	0.0398	2.4232	0.0382	2.3145						
Male life expectancy at age 0	0.0453	1.9201	0.0603	2.5822	0.0586	2.4983						
Initial Infant Mortality							-0.0239	-3.2369	-0.0205	-2.7781	-0.0212	-2.8649
Intial male life expectancy at age 0							-0.0191	-0.628	0.0072	0.2271	0.0015	0.0493
Initial GDP per capita	0.23	0.7232	0.0662	0.2116	0.0993	0.3164	-0.0895	-0.2645	-0.2667	-0.7849	-0.2239	-0.6596
Initial proportion of output in industry	-0.0347	-1.6606	-0.0356	-1.7528	-0.0348	-1.7035	-0.0445	-2.1464	-0.042	-2.057	-0.042	-2.0466
Initial primary education	64.4787	5.6827	51.9738	4.4763	54.5872	4.7325	57.5375	5.2507	47.5982	4.1642	49.8407	4.3971
Initial secondary educaton	-60.2529	-3.2361	-48.538	-2.6349	-49.9631	-2.7008	-71.3754	-3.7725	-63.2485	-3.349	-64.3673	-3.3962
Adj R squared	0.2493		0.2899		0.2823		0.2765		0.2983		0.2925	
R squared	0.2757		0.3185		0.3111		0.3019		0.3265		0.3209	
p-value	0		0		0		0		0		0	
Dependent Variariable	**Female-male difference in Tertiary School Completed**											
	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat	Coefficient	t-stat
Constant	-11.8614	-0.2954	-15.6473	-0.3885	-29.8814	-0.7165	76.03	2.6187	56.436	1.8298	33.1658	0.9617
$MMR_{**}xI_t^{post}$												
I_t^{post}=1 for t>1950			-0.0158	-1.1027					-0.0263	-1.803		
I_t^{post}=1 for t>t*-2					-0.0211	-1.5337					-0.0311	-2.2475
IMR	0.0351	3.3296	0.0317	2.8834	0.0304	2.7784						
Male life expectancy at age 0	0.0307	1.9997	0.0275	1.7617	0.0264	1.6962						
Initial Infant Mortality							-0.005	-0.9971	-0.0066	-1.301	-0.0068	-1.3513
Intial male life expectancy at age 0							0.0249	1.2133	0.0127	0.5894	0.0114	0.5361
Initial GDP per capita	-0.6835	-3.3014	-0.6486	-3.0986	-0.6411	-3.0797	-0.9117	-3.9921	-0.8291	-3.5797	-0.8234	-3.5897
Initial proportion of output in industry	-0.0076	-0.5607	-0.0074	-0.5465	-0.0076	-0.5602	-0.0062	-0.445	-0.0074	-0.5293	-0.0079	-0.5666
Initial primary education	ß	-2.2133	-13.6848	-1.7618	-13.1374	-1.7167	-20.377	-2.7537	-15.7469	-2.0208	-15.3242	-2.0005
Initial secondary educaton	-30.852	-2.5453	-33.3475	-2.7059	-34.1925	-2.7859	-36.4695	-2.8544	-40.2554	-3.1267	-41.0703	-3.2065
Adj R squared	0.2028		0.2037		0.2084		0.1732		0.1828		0.1903	
R squared	0.2308		0.2357		0.2402		0.2023		0.2157		0.2229	
p-value	0		0		0		0		0		0	

Notes
1 All specifications include time effects.
2 The sample comprises individulas 25 years of age and older in 1950-2000. The data is available at 5 year intervals.

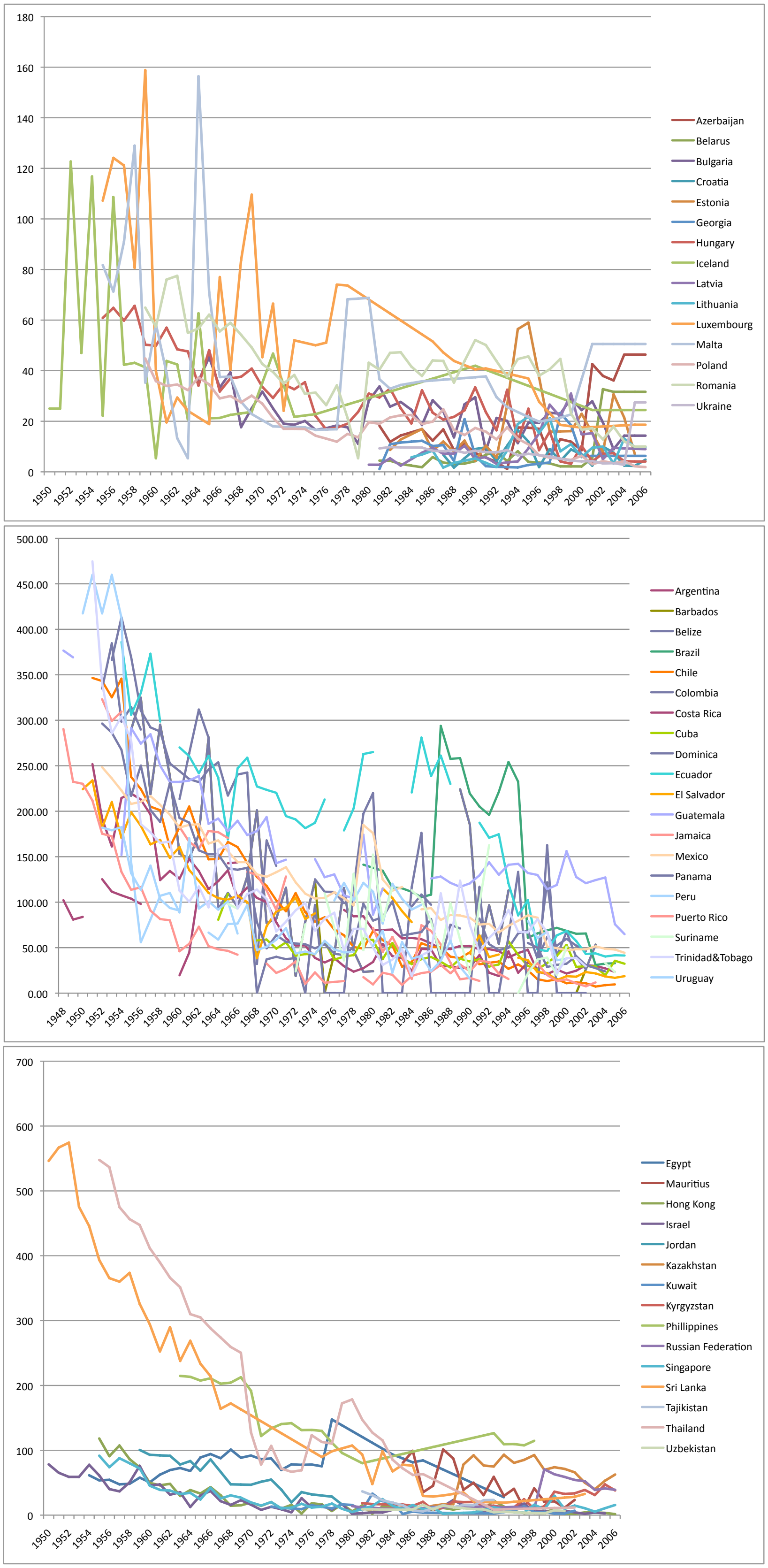
4 Post-War Period

We now discuss the behavior of maternal mortality, infant mortality and fertility in a set of emerging economies in Central and South America, Africa, Asia and Europe. We restrict attention to countries represented in the WHO database for maternal mortality for which at least 25 years of data are available. The data set covers the period 1950-2008, though for most emerging and developing countries data is available for a much shorter period of time. The years in which data is available are reported in the Data Appendix.

Figure 19 presents the behavior of maternal mortality in the sample period for the countries included in the analysis. In all the three regions considered, maternal mortality declines over the sample period, albeit from very different initial levels. In all countries, maternal mortality is more volatile over the sample period, in comparison to its behavior in advanced economies. Most importantly, many countries that experience a decline in maternal mortality that is merely temporary, whereas maternal mortality declines were permanent in all countries in advanced economies.

To analyze the link between maternal mortality and fertility, we first provide descriptive evidence on maternal mortality and infant mortality reduction in these countries, and examine the behavior of fertility over the sample period.

Figure 19: Maternal Mortality in Emerging Economies



Maternal deaths per 100,000 live births. Source: World Health Organization

4.1 Descriptive Evidence

We proceed by identifying episodes of sharp maternal and infant mortality reductions, and episodes of sharp changes in fertility, which we will refer to as baby booms and busts.

Table 7 presents episodes of sharp reductions in maternal and infant mortality, as well as the initial values and the overall change in these variables, over the sample period. There is a striking variation in initial levels of both maternal and infant mortality. The median initial value of maternal mortality is 1.82 deaths per 10,000 live births among European countries, 23 deaths per 10,000 live births in Central and Latin American countries, and 5.35 deaths per 10,000 live births in African and Asian countries. The median change in maternal mortality over the sample period is -34% for European countries, -77% for American countries and -52% for African and Asian countries, however, for many countries maternal mortality rises in the sample period and the initial value is implausibly low. All countries in the former Soviet Union (Estonia, Georgia, Latvia, Lithuania, Kazakhstan and the Russian Federation), as well as Croatia share this pattern, while in Azerbaijan, Belarus, Bulgaria and the Ukraine maternal mortality starts form very low levels and declines very little over the sample period. This pattern strongly suggests that maternal mortality was initially severely under reported in these countries. Sri Lanka and Thailand display the highest initial values of maternal mortality in the sample period, at 45 and 54 deaths per 10,000 live births, respectively, comparable to the value observed in the US in 1940, and they experience the largest percentage declines over the sample period. The Philippines and most Central and Latin American countries display initial values of maternal mortality ranging between 20 and 35 deaths per 10,000 live births, comparable the level in the U.S. in the immediate post-war. While most American countries, with the exception of Brazil, display sizable reductions in maternal mortality over the sample period, with a median of -77%, declines are more modest in other regions.

Several countries experience episodes of sharp reductions in maternal mortality, defined as a decline of at least 60% over a 10 year period[18], though mostly from much lower levels than the advanced economies. Among these, the most ones with initial value of maternal mortality above 20 deaths per 10,000 live births are Dominica in 1964, Peru in 1960, and Thailand in 1967. Latin and Central American countries display the highest median initial maternal mortality, at 17 deaths per 10,000 live births, though episodes in European countries display the largest percentage decline.

All countries in the sample display very sizable reductions in infant mortality over the

[18] We adopt a shorter year span to define episodes of maternal mortality reductions because of data limitations. In addition, in many countries maternal mortality reductions are not permanent, so the episodes of decline exhibit a shorter duration.

sample period, mostly greater than 90%. Median initial infant mortality is highest for African and Asian countries at 112 deaths per 1,000 live births, and American countries at 100 deaths per 1,000 live births. Similar values were recorded in Anglo-Saxon and Northern European countries in the early 1920s. Several countries in Europe also display values of initial infant mortality above 100 deaths per 1,000 live births, including Azerbaijan, Georgia, Hungary, Poland and Romania. The remaining countries in the former soviet block display initial levels of infant mortality close to 60 deaths per 1,000 live births.

All countries in the sample experience episodes of large decline in infant mortality over the sample period, which account for most of the decline over the entire period. For European countries, the median start year for these episodes is 1993, and the initial value of infant mortality is 58 deaths per 1,000 live births. For central and Latin American countries, the median start year is also 1993, and the median value of initial infant mortality is 62, for the African and Asian countries, the median start year is also 1993, and the initial infant mortality is 78 deaths per 1,000 live births.

This suggests a striking difference in the joint behavior of infant and maternal mortality over time in advanced and developing economies. The reduction in maternal mortality is smaller than the decline in infant mortality, though, even for the countries where measurement error and under reporting are a smaller concern, initial maternal mortality is low relative to initial infant mortality. This pattern resembles the one uncovered for Mediterranean countries and Japan in the 1930s. In advanced economies the decline in infant mortality was mostly quite gradual over the twentieth century, in contrast to the reduction in maternal mortality, which was sharp and concentrated in time, the opposite seems to be true in emerging economies. Finally, while in advanced economies the timing on large maternal mortality reductions was mostly synchronized across countries, this is not true for developing countries, where, by contrast, episodes of sharp infant mortality reduction are highly concentrated, and occur mostly in the early 1990s.

Turning to the behavior of fertility, Table 8 displays information on baby booms and busts, as well as the overall change in fertility over the sample period or the available years for the same set of countries. Initial fertility varies widely across countries and across regions. Median initial fertility in the group of European countries is 16 births per 1,000 population, while the corresponding values for Central and Latin America is 38, and for Africa and Asia, 34. Despite this variation, all countries experience large declines in fertility over the sample period, with the median change in fertility equal to -44% for the group of European countries, equal to to -52% for Central and Latin American countries and to -47% for Africa and Asian countries.

We identify the episodes of large swings in fertility, as follows. We define a baby boom

Table 7: Maternal and Infant Mortality Decline

	Episodes of 60% or more decline in maternal mortality over the subsequent 10 years			Episodes of 60% or decline in infant mortality over the subsequent 10 years			Entire sample period			
Europe										
	Year	*Initial maternal mortality*	*% decline over subsequent 10 years*	*Year*	*Initial infant mortality*	*% decline over subsequent 10 years*	*Maternal mortality in first available year*	*% change in maternal mortality over available years*	*Infant mortality in first available year*	*% change in infant mortality over available years*
1 Azerbaijan	None			1993	108.39	-99.09%	1.82	-34.16%	115.67	-98.96%
2 Belarus	None			1993	58.17	-99.05%	0.44	-10.86%	60.75	-99.35%
3 Bulgaria	None			1994	51.43	-96.57%	3.59	-42.00%	65.73	-96.83%
4 Croatia	None			1995	39.49	-97.90%	0.68	32.57%	39.49	-97.73%
5 Estonia	None			1993	61.07	-95.33%	0.86	275.40%	63.00	-94.85%
6 Georgia	None			1993	93.12	-98.99%	0.11	1066.51%	101.56	-98.76%
7 Hungary	None			1993	63.30	-96.58%	6.13	-76.36%	119.62	-98.79%
8 Iceland	1961	7.18	-61.00%	1996	18.91	-82.87%	6.92	-53.21%	43.48	-92.55%
9 Latvia	None			1993	54.57	-98.78%	0.28	466.01%	57.33	-97.22%
10 Lithuania	None			1993	57.68	-98.14%	0.57	160.64%	61.69	-97.57%
11 Luxembourg	1960	11.16	-72.68%	1993	27.92	-86.54%	11.16	-73.77%	81.46	-96.41%
12 Malta	1967	7.38	-71.58%	1993	41.58	-92.93%	8.16	-71.69%	89.29	-97.41%
13 Poland	None			1994	55.42	-97.87%	4.48	-79.59%	143.86	-99.36%
14 Romania	None			1993	77.53	-94.25%	6.49	-39.71%	154.09	-97.46%
15 Ukraine	None			1993	59.05	-98.72%	0.93	-31.33%	59.24	-98.92%
Median	**1961**	**7.38**	**-71.58%**	**1993**	**57.68**	**-97.87%**	**1.82**	**-34.16%**	**65.73**	**-97.57%**
Central and Latin America										
	Year	*Initial maternal mortality*	*% decline over subsequent 10 years*	*Year*	*Initial infant mortality*	*% decline over subsequent 10 years*	*Maternal mortality in first available year*	*% change in maternal mortality over available years*	*Infant mortality in first available year*	*% change in infant mortality over available years*
1 Barbados	None			1995	59.28	-89.15%	28.46	-80.80%	269.20	-97.97%
2 Brazil	None			1994	165.13	-89.31%	14.13	-1.39%	134.07	-89.61%
3 Colombia	None			1993	61.87	-89.60%	36.18	-84.86%	222.07	-97.53%
4 Costa Rica	1969	12.64	-60.02%	1993	51.49	-94.07%	20.69	-86.08%	154.70	-98.14%
5 Cuba	None			1993	50.61	-92.60%	11.61	-67.88%	37.14	-89.96%
6 Dominica	1964	25.55	-62.92%	1996	42.78	-69.94%	31.55	-59.24%	118.53	-89.15%
7 Ecuador	1992	23.75	-61.45%	1993	154.76	-90.48%	36.48	-74.90%	100.00	-90.85%
8 El Salvador	None			1993	119.72	-96.36%	19.19	-83.78%	158.75	-98.04%
9 Guatemala	None			1995	188.76	-92.93%	22.47	-42.23%	103.00	-87.40%
10 Jamaica	1989	5.41	-74.29%	1976	88.01	-62.59%	28.37	-95.27%	76.14	-98.24%
11 Panama	1966	18.72	-62.31%	1995	60.52	-91.53%	25.93	-81.68%	72.39	-93.44%
12 Puerto Rico	1960	14.48	-65.13%	1994	49.91	-94.70%	14.48	-85.33%	66.71	-96.82%
13 Suriname	None			1993	71.02	-90.12%	9.81	-55.61%	47.94	-90.92%
14 Trinidad&Tobago	None			1993	46.00	-85.18%	29.22	-77.17%	152.03	-95.61%
16 Uruguay	1988	4.67	-61.90%	1993	91.30	-98.25%	15.74	-89.88%	54.71	-97.09%
Median	**1969**	**14.48**	**-62.31%**	**1993**	**61.87**	**-91.53%**	**22.47**	**-81.68%**	**100.00**	**-95.61%**
Africa and Asia										
	Year	*Initial maternal mortality*	*% decline over subsequent 10 years*	*Year*	*Initial infant mortality*	*% decline over subsequent 10 years*	*Maternal mortality in first available year*	*% change in maternal mortality over available years*	*Infant mortality in first available year*	*% change in infant mortality over available years*
1 Egypt	1990	9.73	-61.19%	1993	174.63	-97.55%	5.73	-46.49%	168.44	-98.18%
2 Mauritius	None			1993	58.16	-91.73%	8.05	-58.74%	58.16	-94.29%
3 Hong Kong	1960	11.28	-65.85%	1993	29.86	-96.12%	11.28	-92.27%	131.22	-99.34%
4 Israel	1966	4.62	-67.08%	1993	39.60	-97.12%	5.70	-85.01%	63.20	-98.65%
6 Kazakhstan	None			1993	109.80	-93.33%	1.01	714.01%	112.60	-92.73%
7 Kuwait	1987	1.78	-82.74%	1993	68.18	-99.46%	1.33	-56.58%	77.00	-99.25%
8 Kyrgyzstan	None			1993	136.91	-98.81%	1.85	-22.37%	137.01	-98.95%
9 Phillippines	None			1993	79.81	-85.41%	21.47	-46.43%	144.15	-92.02%
10 Russian Federation	None			1993	76.23	-98.30%	1.39	46.26%	78.47	-97.41%
11 Singapore	1960	8.86	-62.01%	1993	31.68	-98.06%	8.86	-90.02%	97.21	-99.09%
12 Sri Lanka	1985	9.12	-60.23%	1993	84.23	-97.14%	45.45	-95.31%	149.46	-98.57%
14 Thailand	1967	39.04	-64.84%	1993	37.32	-94.67%	53.58	-98.03%	111.98	-99.06%
Median	**1976**	**8.99**	**-63.43%**	**1993**	**78.02**	**-97.60%**	**5.35**	**-51.51%**	**112.29**	**-98.76%**

Notes: Based on 5 year moving averages of all data. Available years by country listed in the Data Appendix.

Maternal deaths per 10,000 live births, infant deaths per 1,000 live births. Source: World Health Organization.

(bust) as an episode of 10% or more rise (decline) in fertility over a 15 year period. Table 8 reports the initial year, the initial level of fertility and the magnitude of the change in fertility for each episode.

Only a very limited number of countries experience baby booms, and these episodes are significantly smaller in magnitude when compared to those experienced by advanced economies in conjunction with the maternal mortality decline. Among European countries, Hungary, Luxembourg, Poland and Romania experience a baby boom in 1966, 1978, 1970 and 1965, respectively. Despite the low initial levels of fertility, the baby booms are small, ranging between 11 and 17%. Among American countries, Brazil experiences a baby boom in 1966, and Jamaica and Peru experience a baby boom in 1956. Initial fertility is relatively low in Brazil, but quite high in both Jamaica and Peru, and the corresponding median change in fertility is 11%. Only the Philippines experience a baby boom in 1965 among African and Asian countries, with initial fertility at 25 births per 1,000 population and a corresponding rise in fertility of 23%.

All countries in the sample experience a baby bust. Among European countries, the median start date is 1985 and most episodes are quite close to this date. Despite the low level of median initial fertility, at 16 births per 1,000 population, the busts are quite large, with a median of -41%. Busts tend to occur much earlier in Central and Latin American countries, with a median start year of 1964, and are typically smaller in magnitude, with a median decline of -31%, despite the higher level of initial fertility, at 39 deaths per 1,000 live births. African and Asian countries display more heterogeneity. The median start year is 1979, while initial fertility is 33, with a median change of -35%. For both boom and bust episodes there no significant correlation between initial fertility and the magnitude of the change in fertility.

Table 8: Fertility Dynamics

Europe

	Baby Booms			Baby Busts			Entire sample period	
	Year that marks the start of a baby boom	*Initial Fertility*	*% rise in fertility in the subsequent 15 years*	*Year that marks the start of a baby bust*	*Initial Fertility*	*% decline in fertility in the subsequent 15 years*	*Fertility in first available year*	*% change in fertility over available years*
1 Azerbaijan	None			1988	26.46	-44.32%	26.30	-44.18%
2 Belarus	None			1985	16.43	-43.58%	16.22	-44.05%
3 Bulgaria	None			1978	16.20	-30.68%	16.08	-47.48%
4 Croatia	None			1987	12.46	-20.23%	12.49	-20.40%
5 Estonia	None			1988	15.67	-40.90%	15.42	-39.96%
6 Georgia	None			1985	18.17	-42.75%	18.09	-41.51%
7 Hungary	1966	13.48	10.84%	1956	20.51	-28.82%	20.51	-53.22%
8 Iceland	None			1958	28.09	-26.10%	28.04	-47.28%
9 Latvia	None			1987	15.69	-47.23%	14.15	-41.47%
10 Lithuania	None			1987	16.05	-41.38%	15.22	-38.19%
11 Luxembourg	1978	11.10	16.71%	1962	16.00	-30.06%	15.48	-18.71%
12 Malta	None			1956	27.21	-39.13%	27.21	-59.15%
13 Poland	1970	16.68	12.67%	1983	19.28	-41.33%	24.72	-60.07%
14 Romania	1965	16.09	16.69%	1978	19.27	-32.44%	20.19	-49.57%
15 Ukraine	None			1986	14.95	-44.75%	14.62	-44.08%
Median	**1968**	**14.78**	**14.68%**	**1985**	**16.43**	**-40.90%**	**16.22**	**-44.08%**

Central and Latin America

	Baby Booms			Baby Busts			Entire sample period	
	Year that marks the start of a baby boom	*Initial Fertility*	*% rise in fertility in the subsequent 15 years*	*Year that marks the start of a baby bust*	*Initial Fertility*	*% decline in fertility in the subsequent 15 years*	*Fertility in first available year*	*% change in fertility over available years*
1 Barbados	None			1956	32.69	-32.91%	32.69	-55.31%
2 Brazil	1966	21.50	10.84%	1956	43.56	-45.62%	43.56	-51.81%
3 Colombia	None			1962	39.77	-20.44%	38.04	-41.74%
4 Costa Rica	None			1961	47.39	-36.42%	43.24	-51.89%
5 Cuba	None			1965	34.23	-51.34%	28.22	-53.79%
6 Dominica	None			1962	43.22	-40.15%	44.31	-62.35%
7 Ecuador	None			1972	38.24	-40.16%	46.31	-47.84%
8 El Salvador	None			1967	46.34	-20.44%	49.24	-52.67%
9 Guatemala	None			1956	50.20	-15.25%	50.20	-27.22%
10 Jamaica	1956	32.64	10.15%	1971	35.96	-30.23%	32.64	-30.29%
11 Panama	None			1964	39.21	-24.55%	36.07	-38.49%
12 Puerto Rico	None			1956	35.33	-26.73%	35.33	-57.06%
13 Suriname	None			1964	43.38	-32.53%	43.38	-54.11%
14 Trinidad&Tobago	None			1984	28.29	-47.74%	38.21	-63.03%
16 Uruguay	None			1963	23.87	-15.20%	20.50	-20.99%
Median	**1961**	**27.07**	**10.50%**	**1963**	**39.21**	**-32.53%**	**38.21**	**-51.89%**

Africa and Asia

	Baby Booms			Baby Busts			Entire sample period	
	Year that marks the start of a baby boom	*Initial Fertility*	*% rise in fertility in the subsequent 15 years*	*Year that marks the start of a baby bust*	*Initial Fertility*	*% decline in fertility in the subsequent 15 years*	*Fertility in first available year*	*% change in fertility over available years*
1 Egypt	None			1986	37.86	-28.04%	42.00	-35.88%
2 Mauritius	None			1956	44.20	-35.46%	44.20	-62.12%
3 Hong Kong	None			1957	36.50	-43.94%	36.36	-78.51%
4 Israel	None			1956	30.37	-14.50%	30.37	-29.21%
6 Kazakhstan	None			1987	26.63	-43.03%	24.37	-37.76%
7 Kuwait	None			1976	39.70	-30.62%	44.78	-49.70%
8 Kyrgyzstan	None			1987	31.50	-34.04%	30.67	-32.26%
9 Phillippines	1965	25.13	23.42%	1985	32.80	-25.83%	30.50	-22.62%
10 Russian Federation	None			1986	16.89	-47.82%	15.91	-43.31%
11 Singapore	None			1963	36.67	-50.04%	45.02	-71.63%
12 Sri Lanka	None			1981	28.07	-30.74%	37.60	-52.06%
14 Thailand	None			1971	33.60	-41.33%	31.39	-55.27%
Median	**1965**	**25.13**	**23.42%**	**1979**	**33.20**	**-34.75%**	**33.87**	**-46.51%**

Notes: Baby booms (busts) are defined as a rise (decline) in fertility of at least 15% in the subsequent 15 years. Available years are listed in the Data Appendix.

Births per 1,000 population. Source: World Health Organization and Mitchell (1998).

5 Conclusion

We have show that a decline in maternal mortality is associated with a boom-bust response in fertility and a permanent rise in women's human capital with respect to men, providing a novel integrated explanation for these phenomena that occurred in advanced and emergin economies during the twentieth century. Many developing countries still exhibit extremely high rates of maternal mortality. However, given their high fertility rates and high infant mortality rates in these countries it is unlikely that a reduction in maternal mortality will lead to a boom-bust response in fertility for these countries.

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A Proofs for Section 2

The first order necessary conditions for the mothers' problem are:

$$-v_b(b,e') + \kappa(sb)U'(e';\mu') \leq 0, \tag{8}$$

with equality for $e > 0$, and

$$-v_{e'}(b,e') - \mu u((1+\varepsilon e)w) + \kappa'(sb)sU(e';\mu') = 0, \tag{9}$$

since Inada condition on the utility from children implies that $b > 0$ at the optimum. The envelope condition is:

$$U'(e;\mu) = (1 - \mu b)u'(w(1 + \varepsilon e))w\varepsilon. \tag{10}$$

Proof of Proposition 1:

Totally differentiating the system of first order necessary conditions (8)-(9) with respect to μ for $\mu = \mu'$, and simplifying yields:

$$[-v_{e'e'}(b,e') + \kappa(sb)U''(e';\mu)]\frac{\partial e'}{\partial \mu} + [-v_{e'b}(b,e') + \kappa'(sb)sU'(e';\mu)]\frac{\partial b}{\partial \mu} = -\kappa(sb)\frac{\partial U'(e';\mu)}{\partial \mu},$$

$$[-v_{be'}(b,e') + \kappa'(sb)sU'(e';\mu)]\frac{\partial e'}{\partial \mu} + \left[-v_{bb}(b,e') + \kappa''(sb)s^2U(e';\mu)\right]\frac{\partial b}{\partial \mu} = u((1+\varepsilon e)w) - \kappa'(sb)s\frac{\partial U(e';\mu)}{\partial \mu}.$$

Solving:

$$\frac{\partial e'}{\partial \mu} = \frac{-[-v_{e'b}(b,e') + \kappa'(sb)sU'(e';\mu)]}{[-v_{e'e'}(b,e') + \kappa(sb)U''(e';\mu)]}\frac{\partial b}{\partial \mu} - \frac{\kappa(sb)\frac{\partial U'(e';\mu)}{\partial \mu}}{[-v_{e'e'}(b,e') + \kappa(sb)U''(e';\mu)]},$$

$$\left\{\frac{detH_V}{[-v_{e'e'}(b,e') + \kappa(sb)U''(e';\mu)]}\right\}\frac{\partial b}{\partial \mu}$$
$$= \frac{[-v_{be'}(b,e') + \kappa'(sb)sU'(e';\mu)]}{[-v_{e'e'}(b,e') + \kappa(sb)U''(e';\mu)]}\kappa(sb)\frac{\partial U'(e';\mu)}{\partial \mu} + u((1+\varepsilon e)w) - \kappa'(sb)s\frac{\partial U(e';\mu)}{\partial \mu}.$$

By (10):

$$\frac{\partial U'(e;\mu)}{\partial \mu} = -bu'(w(1+\varepsilon e))w\varepsilon < 0, \tag{11}$$

$$\frac{\partial U(e;\mu)}{\partial \mu} = -bu(w(1+\varepsilon e)) < 0. \tag{12}$$

By Assumption 1, $detH_V > 0$ and $[-v_{e'e'}(b,e') + \kappa(sb)U''(e';\mu)] < 0$. Thus, condition (3) guarantees $\frac{\partial b}{\partial \mu} < 0$ and $\frac{\partial e'}{\partial \mu} < 0$.■

Proof of Proposition 2:

Totally differentiating the system of first order necessary conditions (8)-(9) with respect to e and simplifying yields:

$$[-v_{e'e'} + \kappa(sb)U''(e';\mu')]\frac{\partial e'}{\partial e} + [-v_{e'b} + \kappa'(sb)sU'(e';\mu')]\frac{\partial b}{\partial e} = 0,$$

$$[-v_{e'b} + \kappa'(sb)sU'(e';\mu')]\frac{\partial e'}{\partial e} + \left[-v_{bb} + \kappa''(sb)s^2U(e';\mu)\right]\frac{\partial b}{\partial e} = \mu u'(w(1+\varepsilon e))\varepsilon w.$$

Substituting for $\frac{\partial b}{\partial e}$ and simplifying the second equation:

$$\frac{\partial e'}{\partial e} = -\frac{[-v_{e'b} + \kappa'(sb)sU'(e';\mu')]}{[-v_{e'e'} + \kappa(sb)U''(e';\mu')]}\frac{\partial b}{\partial e}, \tag{13}$$

$$\frac{\partial b}{\partial e} = \left\{\frac{detH_V}{[-v_{e'e'} + \kappa(sb)U''(e';\mu')]}\right\}^{-1} \mu u'(w(1+\varepsilon e))\varepsilon w, \tag{14}$$

By Assumption 1, $detH_V > 0$ and $[-v_{e'e'}(b, e') + \kappa(sb)U''(e';\mu)] < 0$. Thus, $\frac{\partial b}{\partial e} < 0$. In addition, condition (3), equation (13) implies $\frac{\partial e'}{\partial e} > 0$.■

B Data

TBA

C Empirical Analysis: Additional Results

Table 9 reports the correlations between the variables considered and initial maternal mortality.

Table 9: Correlations with Initial Maternal Mortality

Correlations	MMR	Fertility	IMR	CDR	Male life expectancy at birth	GDP per capita	Proportion of GDP from industry	Primary education completion	Secondary education completion	Detrended GDP per capita	Neutrality in WWI	Casualties in WWII	Lagged detrended GDP, 1 year	Lagged detrended GDP, 3 year	Lagged detrended GDP, 5 year	Lagged detrended GDP, 10 year
MMR	1															
Fertility	0.1595	1														
IMR	-0.2406	0.182	1													
CDR	0.4191	0.0399	0.1776	1												
Male life expectancy at birth	-0.4039	-0.2212	-0.4551	-0.6936	1											
GDP per capita	0.4677	-0.2099	-0.391	-0.1603	0.2121	1										
Proportion of GDP from industry	-0.2068	-0.0004	-0.1229	0.0042	-0.0973	0.0557	1									
Primary education completion	0.415	0.4099	-0.3263	-0.2588	0.2452	0.3459	-0.3236	1								
Secondary education completion	-0.264	0.2122	-0.0737	-0.2499	0.3209	0.0203	0.1412	0.0083	1							
Detrended GDP per capita	0.618	0.0985	-0.1053	0.5899	-0.4024	0.2707	0.0084	0.1504	-0.3407	1						
Neutrality in WWI	-0.2503	-0.3005	0.0701	0.2605	0.0701	-0.2703	-0.2033	-0.3304	-0.2504	-0.2904	1					
Casualties in WWII	0.2339	0.3769	-0.1052	0.0233	-0.2119	-0.0762	0.1361	0.1722	0.3194	0.173	-0.7103	1				
Lagged detrended GDP, 1 year	0.2887	-0.0466	-0.1729	0.6012	-0.2302	-0.0075	0.0893	-0.0842	-0.1256	0.8316	-0.03	-0.0107	1			
Lagged detrended GDP, 3 year	0.4316	-0.0218	-0.2842	0.6283	-0.2858	0.0556	0.1175	0.0271	-0.2076	0.8586	-0.0901	0.1189	0.9564	1		
Lagged detrended GDP, 5 year	0.6677	0.1978	-0.1398	0.5478	-0.4107	0.3414	0.0183	0.2556	-0.4144	0.9699	-0.3304	0.1798	0.7293	0.794	1	
Lagged detrended GDP, 10 year	0.5774	0.1279	-0.2	0.4011	-0.1527	0.3203	-0.4129	0.3263	-0.1128	0.7774	-0.1702	0.0107	0.6887	0.6632	0.7414	1

Red: significance at 1% level. Blue: significance at 5% level. Green: Significance at 10% level.

D Predictors of Maternal and Infant Mortality

TBA

E Empirical Analysis with Crude Birth Rate

TBA