The Effects of Intrauterine Malnutrition on Birth and Fertility Outcomes: Evidence from the 1974 Bangladesh Famine

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Abstract

This paper uses the Bangladesh Famine of 1974 as a natural experiment to estimate the impact of intrauterine malnutrition on sex ratio at birth and infant mortality, and also on post-Famine pregnancy outcomes for women who were exposed to the Famine while pregnant. Using the 1996 Matlab Health and Socioeconomic Survey (MHSS), we find that children who were *in utero* during the most severe period of the Famine were 2 percent more likely to die within one month or one year of birth compared to children who were not *in utero* during the Famine. Furthermore, controlling for pre-Famine fertility, we find that women who were pregnant during the Famine experienced a higher number of stillbirths in the post-Famine years. This increase appears to be driven by an excess number of male stillbirths.

JEL Codes: I10, I12, J12, J13.

Keywords: famine, fertility outcomes

1 Introduction

The Bangladesh famine of 1974 (henceforth the Famine) was one of the worst famines recorded in the modern history of Bangladesh, with between 450,000-1.5 million deaths (Alamgir 1980). We use the Famine as a natural experiment to examine the effects of intrauterine malnutrition on infant mortality and gender. In addition, we study the impact of malnutrition during pregnancy on the post-Famine fertility outcomes of those women who were pregnant during the famine.

A growing body of literature examines the impact of *in utero* shocks, such as disease epidemics, conflicts, and air pollution, on infant health (Almond 2006; Currie 2009; Mansour and Rees 2011). However, despite the continuing prevalence of malnutrition in many developing countries, only a few studies have examined the relationship of infant health to intrauterine malnutrition (DeRose et al. 2000). Lumey and Stein (1997) found that exposure to intrauterine malnutrition during the Dutch famine led to lower birth weight. Almond et al. (2007) examined the impact of intrauterine malnutrition resulting from the Chinese famine of 1959-1961 on subsequent adult outcomes, finding that men and women who were exposed to the famine *in utero* were more likely to be illiterate and less likely to work or be married. In addition, their data on surviving adult cohorts suggested that prenatal exposure to malnutrition reduced the likelihood of male births, suggesting that males are more vulnerable to *in utero* shocks.

We contribute to the existing literature in two important ways. First, our data allow us to examine the impact of intrauterine malnutrition on the gender of the infant. This is in contrast to existing studies among humans, which examined the link between malnutrition

and sex ratio only among surviving cohorts (Almond et al. 2007).[1,2] Second, we study the impact of malnutrition on the likelihood of infant mortality and on the likelihood of stillbirths and miscarriages during the post-Famine years. In particular, we document a lingering negative effect of exposure to the Famine during pregnancy on the probability of having a future stillbirth. To our knowledge, this is the first study to demonstrate a relationship between malnutrition during pregnancy and post-Famine fertility outcomes.

The primary data source is the 1996 Matlab Health and Socioeconomic Survey (MHSS). The MHSS was administered to 4,364 households located in the Matlab district of Bangladesh. It contains information on approximately 25,000 live births, gathered from the fertility history of 5,082 women. It also includes information on miscarriages, stillbirths, infant mortality, and key demographic characteristics such as mother's age at each birth, age at menarche, age at marriage, and education of spouse.

Our results show that children who were *in utero* during the most severe months of the Famine (born during 9/1974-12/1975) were about 2 percent more likely to die within one month or one year of birth. These results are robust to the inclusion of mother fixed effects in the regression. When we decompose the sample by gender, we further find that male fetuses exposed to the famine have a higher probability of infant mortality than female ones. In addition, we find suggestive evidence that the Famine impacted the male-to-female sex ratio at birth, though these results are statistically weaker.

We also document a negative relationship between exposure to the Famine and future

[1] Epidemiological studies have shown that maternal malnutrition is an important environmental factor that increases the percentage of female live births. For instance, Huck et al. (1986) found that a reduction in caloric intake administered to hamsters decreases the likelihood of a live male birth.

[2] An exception is Anderson and Bergström (1998), who found that prenatal malnutrition, measured by maternal stature and obesity, is associated with a lower male-to-female sex ratio at birth.

fertility outcomes. Specifically, controlling for pre-Famine fertility, we find that women who had a pregnancy outcome (miscarriage, stillbirth, or live birth) between January of 1976 and July of 1976 were about 2 percent more likely to have a stillbirth during future pregnancies.[3] Similar to the infant mortality results, this effect appears to be driven by an excess number of male stillbirths. To our knowledge, this is the first paper to document such a long-lasting effect of malnutrition on fertility outcomes. As a robustness check, we estimate all of our results using two placebo treatment years (1964 and 1984, years where there was no famine) and find no evidence for the results described above. These results suggest an important role for famine aid in targeting male infants and pregnant women, who appear to be vulnerable to prenatal malnutrition.

The rest of the paper is organized as follows. Sections 1.1-1.2 provide a brief background of the Famine and a review of the epidemiological and economics famine literature. Section 2 describes the MHSS data in detail. Section 3 discusses the empirical strategy, and section 4 reports our main results and robustness checks. We conclude in section 5.

1.1 Previous studies on the impact of famines

Previous studies have associated prenatal exposure to famine with adverse outcomes for infants at birth and with an array of long-term outcomes in adulthood (Almond et al. 2007). Only a handful of studies, however, have examined the impact of prenatal malnutrition on infant mortality. Hart (1993) found no evidence that prenatal exposure to the 1944-1945 Dutch Famine was associated with an increase in infant mortality.[4] In contrast, Scott et al.

[3] This birth window means that the mother would have been exposed to at least 9 months of famine before conceiving, but she still conceived before the famine ended.

[4] Infant mortality during famines (in contrast to *in utero* exposure) is a well-documented phenomenon. Lindeboom et al. (2007), for instance, estimate that about 25 percent of children below 1 year of age died

(1995) found that the 1623 famine in northern England did increase infant mortality rates, especially for infants who were exposed during the later stages of pregnancy. This result coincides with Lumey and Stein (1997), who studied the impact of intrauterine malnutrition in the Dutch famine to find that reduced nutrition in the third trimester resulted in lower birth weights.[5] Thus, there is some evidence that malnutrition shocks may be especially harmful to developing fetuses during the late stages of pregnancy and soon after birth.

Prenatal malnutrition in mammals has been associated with a low male-to-female ratio at birth (Huck et al. 1986; Meikle and Drickamer 1986). The impact of malnutrition on gender among humans, however, remains elusive, with quasi-experimental studies focusing on surviving cohorts rather than at the sex ratio at birth. Stein et al. (2004), for instance, found no association between exposure to the Dutch Famine of 1944-1945 and an excess of female births. Almond et al. (2007), on the other hand, found that exposure to the Chinese Famine of 1959-1961 reduced the adult male-to-female sex ratio among those who were prenatally exposed to the famine, and interestingly, also among their children.[6] To our knowledge, no other study has yet examined the impact of famine during pregnancy on future, post-famine, pregnancy outcomes.

during the Dutch Potato Famine of 1864-1847. Moreover, infant mortality rates increased substantially during the Finland famine of 1866-1868 and during the 1941-1944 siege of Leningrad (Kannisto et al. 1997).

[5] Almond and Mazumder (2011), on the other hand, found that reduced nutrition in the *early* stages of pregnancy experienced during the Islamic holy month of Ramadan resulted in lower birth weight. As the authors argue, these results are consistent with the hypothesis that nutrition early in the pregnancy matters but is also consistent with the hypothesis that prenatal stress experienced early in the pregnancy increases the probability of a low-birth-infant.

[6] Almond et al. (2007) rely on the Trivers-Willard (1973) hypothesis, which states that parents in poor economic conditions should favor more female to male births, in order to interpret the results on the second generation's reduced sex ratio.

1.2 Famine background

Bangladesh, formerly a part of India (known as East Bengal then East Pakistan), became independent in 1971. While part of the Indian colony, Bangladesh experienced massive death and suffering during the Great Bengal Famine of 1943. The causes and severity of this famine have been studied by both the Famine Inquiry Commission (1945) and by Amartya Sen (1981), largely with the goal of avoiding a repetition of the tragedy. However, Bangladesh suffered another significant famine in 1974. Toward the middle of that year, severe flooding led to a sharp rise in unemployment, particularly among rural farmers and laborers (Sen 1981). Although food availability remained unaffected until the harvest period later in the year, food prices began to rise immediately toward an eventual increase of 500 percent (Dyson 1991). While the precise cause of these increased prices remains unclear, the most likely factors appear to be macroeconomic and include a combination of inflation and speculation about future price increases (Sen 1981). Regardless, the unemployment and dramatic price increases placed a severe burden on rural areas.

The famine itself began in March of 1974, reaching its peak between July and October. It began to subside by the end of that year, although the impact on people due to high food prices and increased mortality lasted well into 1975 (Alamgir 1980). Figure 1 depicts the price of medium rice in Bangladesh from July 1972 until June 1976. The nationwide price of rice did not peak until February of 1975, returning to pre-Famine levels by the end of that year. The same pattern existed in the district of Chittagong, home of Matlab district and the population surveyed in our data. In this region, the price peaked at a higher point in March of 1975.

The Famine and high food prices led to increased mortality rates that persisted through 1976 (Razzaque et al. 1990). Estimates of fatalities range from 450,000 to well over a million (Alamgir 1980), which comprises approximately 0.6-1.3 percent of the estimated national population (United Nations 2002). Dyson (1991) uses Matlab data to plot mortality rates in Bangladesh before, during, and after the Famine (see Figure 8, page 287), showing a peak death rate in early 1975 that remained high well after the Famine ended, since many were weakened and sickened by the Famine. In fact, the death rate for both infants and all ages was higher in 1975 than in 1974 (Dyson 1991).

Although female child mortality rates tend to be higher than male rates in Matlab during normal years (Fauveau and Chakraborty 1994), the Famine resulted in significant but similar increases in child mortality rates among *both* male and female children (D'Souza and Chen 1980; Koenig and D'Souza 1986; Bairagi 1986). Moreover, fertility rates declined by about 34 percent during 1974-1975, before increasing by 17 percent in the post-Famine years, thereby partially offsetting the Famine's effect (Razzaque 1988).

2 Data

The 1996 Matlab Health and Socioeconomic Survey is a cross-sectional data set sampling 4,364 households in Matlab district, a poor, rural, agricultural area of Bangladesh approximately 55 km southeast of Dhaka (Rahman et al. 1999). These households cover 2,687 baris (groups of households living and working together, sharing a common outdoor space), which comprise a one-third random sample of all Matlab baris. All women aged 15 and older in the sample were asked about their fertility history, including previous preg-

nancy and birth outcomes. They were also asked about any subsequent mortality outcomes for their children. From this information, we are able to gather the date, sex, relative size at birth, birth outcome (miscarriage, stillbirth, or live birth), and neonatal and infant mortality outcomes for 24,916 children born between 1919 and 1996. We are able to supplement this information with demographic characteristics of the mother, including her age at the pregnancy outcome, age at first marriage, years of education, and adult height (in centimeters). We also know the number of older brothers and sisters for each child.

Our goal is to examine the effects of the 1974 famine on birth and subsequent fertility outcomes. Examining the prices of rice in Figure 1 suggests that the most severe period of the Famine occurred between August 1974 and October 1975, when prices were more than 50 percent above pre-Famine levels. Thus, we first compare the birth outcomes for all live births occurring between September 1974 and December 1975 to live births occurring in other periods between 1970 and 1980.[7] Children born within this September 1974 – December 1975 treatment window were *in utero* during the most severe part of the famine for at least one full month of their third trimester.[8] This definition of the treatment is guided by the famine literature that has provided evidence that malnutrition may be particularly harmful to fetuses during the last trimester of pregnancy (Lumey and Stein 1997).

Our outcomes of interest include whether the child is male and whether the child died during the first month or year after birth. Table 1a presents the mean values of these key

[7]When the specific month of birth was not remembered or unavailable, fieldworkers often coded the birth as occurring during January. Thus, the data records an inaccurately large number of January births. The main specifications of this paper are estimated while including these January births. However, all of the results (available upon request) are qualitatively robust to the exclusion of all January births from the sample.

[8]Thus, we exclude from this initial treatment group infants who were exposed to the Famine only in their first trimester and infants who were exposed only in their first and second trimesters.

outcomes for children who were *in utero* during the Famine, the means for children who were *in utero* in other periods, and the difference between them. Children *in utero* during the Famine have significantly higher mortality rates in the first month and year after birth. These children are also less likely to be male, although this difference is not statistically significant. There is no other statistically significant difference between children on any other observable characteristic, such as mother's age at first marriage or mother's age at birth.

In order to determine whether the Famine had a lasting impact on subsequent fertility, Table 1b compares key post-Famine fertility outcomes of women who became pregnant after a long period of exposure to the Famine (had a live birth, stillbirth, or miscarriage between January 1976 and July 1976) to all other women aged 15 and older who were not pregnant during the Famine. Women who experience a pregnancy outcome between January 1976 and July 1976 would have become pregnant after at least nine months of exposure to the Famine but before the Famine itself was over. Thus, in contrast to the immediate effects we expect to see on children *in utero*, we hypothesize that malnutrition may take longer to impact the adult mothers themselves. This argument is motivated by the famine literature, which has documented that the effects of malnutrition among adults peak later than among children, toward the end stages of a nutritional emergency (Davis 1996; Salama and Collins 2000). One important reason why adult malnutrition and mortality becomes more severe at a later stage than it does for children stems from the proportionately lower energy needs of adults (Collins 1995). Other reasons for the late impacts include a tendency of international aid programs to focus heavily on child malnutrition (treatment centers for adults are almost nonexistent) and a hesitation among adults to leave work or agricultural fields for treatment

(Collins 1995; Salama and Collins 2000). In addition, Davis (1996) notes that the extent of vulnerability to malnutrition may simply vary among age groups. It is reasonable to believe that infants *in utero* or just after birth require adequate nutrition immediately in order to supply their growth needs, while adults who are fully grown may be better able to endure short periods of malnutrition before suffering substantial adverse impacts.

After separating women who were fertile during the Famine according to whether they became pregnant before the famine ended but still following at least nine months of Famine exposure, we then examine their post-Famine fertility outcomes for every pregnancy outcome that occurred subsequent to 1977. Limiting the post-Famine pregnancy outcomes to only those occurring after 1977 ensures that these outcomes are not affected by any direct impacts of the Famine itself, which had been over for a year by that time. Specifically, we are interested in whether the post-Famine pregnancies resulted in miscarriages or stillbirths. As can be seen in Table 1b, we find little evidence that women who became pregnant after exposure to the Famine were more likely to have a post-Famine miscarriage. In contrast, the simple mean comparison suggests that women who were pregnant during the Famine were more likely to have a stillbirth in a future, post-Famine pregnancy, and particularly more likely to have a male stillbirth. The results also suggest that women who were pregnant during the Famine are positively selected on observables. Specifically, they have higher educational levels, were married to more educated husbands, and married at a younger age. Moreover, we find that they had a larger number of sons before the Famine.[9]

[9] Although the fertility histories reported by women can be cross-checked against birth records in the vital events database of Matlab, there always remains a small possibility that women are intentionally biased in the recall of their fertility history toward (or against) remembering stillborn male children compared to stillborn females. If women with living sons are less likely to be nervous about reporting male stillbirths than women without many sons, then this difference would place an upward bias on our results for stillbirth outcomes.

3 The Empirical Model

3.1 Infant's outcomes

We start by estimating the following probit regression for children born between 1970 and 1980:[10]

$$C_i = \alpha + \beta_1 \text{Famine}_i + \beta_2 YOB_i + X_i\delta + \epsilon_i \tag{1}$$

where C_i is the outcome of infant i. To investigate the impact of exposure to the Famine on the sex ratio at birth, C_i takes the value of 1 if the child is male and zero otherwise. For infant mortality, C_i takes the value of 1 if the child died within one month or one year of birth, and zero otherwise. Famine_i is an indicator variable that equals 1 if the child was exposed to the Famine while *in utero* (i.e. was born between September 1974 and December 1975). In Table 4, we present estimates allowing for this exposure window to vary.

The vector X includes a set of demographic characteristics controlling for mother's education, age at first marriage, age at birth and age at birth squared, her height in 1996 (in cm), number of older brothers and sisters (born before 1974), and variables comparing the weight of the infant to other infants (i.e. much bigger, bigger than, smaller then, or same size as other babies).[11] We also add controls for season of birth and whether the mother's village is part of the treatment group of a Maternal and Child Health and Family Planning services program operating in the area.[12] Furthermore, including a linear year of birth trend,

[10] All the regressions were also estimated only for children born between 1973 and 1977 and using the entire sample of births 1919-1996. The results are qualitatively similar.

[11] Birth weight is a potential channel through which *in utero* exposure to Famine may impact infant mortality. The results presented are similar in magnitude and significance when we exclude the indicator variables for relative size at birth as reported by the mother.

[12] Season of birth dummies include whether the child was born during the monsoon season (June-October) or the dry winter season (November-February), with the omitted category being the pre-monsoon hot season (March-May). Infant deaths are significantly higher during the winter season, largely due to agricultural

YOB_i, ensures that β_1 measures the difference in outcomes for children born in the treatment window separate from the cohort trend (Almond 2006). Standard errors are clustered at the bari level to account for any serial correlation.

It is likely, however, that women who were pregnant during the Famine are different from women who did not get pregnant during the Famine on some important unobservable dimensions. Since many of the women in our sample gave birth to more than one child during the period of 1970-1980, we are able to include mother fixed effects in equation (1) and estimate the following OLS regression:

$$C_i = \alpha + \beta_1 \text{Famine}_i + \beta_2 YOB_i + X_i\delta + m_i + \eta_i \quad (2)$$

The vector X in equation (2) includes similar variables included in equation (1), with the exception of mother's education, her age at first marriage, and her height. In order to ensure that our results are not spurious, we also report results from estimating equations (1) and (2) using births between 1960-1970 and between 1980-1990, where we assign 1964 and 1984 as placebo treatment years, respectively.

3.2 Mother's outcomes

The impact of exposure to the Famine on future fertility outcomes is estimated from the following probit regression:

$$M_{ij} = \alpha + \beta_1 FamMother_j + \beta_2 YOB_i + Z_j\gamma + X_{ij}\delta + \varepsilon_{ij} \quad (3)$$

cycles.

where M is an indicator variable that equals 1 if a post-Famine pregnancy i resulted in a miscarriage or stillbirth for woman j, and zero otherwise. Our main treatment group in this specification differs from the one we considered for the child's outcomes. Specifically, the indicator variable $FamMother$ takes the value of 1 if the mother had any pregnancy outcome between January of 1976 and July of 1976 (miscarriage, stillbirth, or live birth). This birth window implies that the mother conceived between April of 1975 and October of 1975 and would have been exposed to at least 9 months of the Famine while pregnant. In addition to the controls included in vector X, the vector Z includes the total number of pre-Famine (prior to 1974) live male and female births, post-Famine live births by gender (births after 1976) and spouse's education. In Table 6, we reproduce the results using different periods of exposure to Famine. Because $FamMother$ does not vary by pregnancy outcome, we cannot include fixed effects for the mother in this specification.

4 The Results

4.1 Children Outcomes

Table 2 presents the estimation results for equations (1) and (2). Looking at the implied marginal effects, children born between September of 1974 and December of 1975 are 2 percent less likely to be male (column 2), although this estimate is not significant at conventional levels. As one would expect, since the gender of a child can be considered random, the coefficient estimates for most of the controls listed in the previous section (not reported in the Table) are small and not statistically significant.

Columns 4 and 7 of Table 2 show estimation results of equation (1) using infant mortality at 1 month and 1 year as the outcomes. Marginal effects evaluated at the mean are shown in columns 5 and 8. Children born during the treatment period (who were *in utero* during the famine) are 2 percent more likely to die within their first month after birth and also 2 percent more likely to die within their first year.

It could be the case that mothers who opt to get pregnant during famine periods are unobservably different from mothers who do not. For instance, maybe more cautious mothers who are concerned for their child's health avoid becoming pregnant during food shortages.[13] To control for such traits, we include mother fixed effects in the regressions in columns 6 and 9. The result for death by 1 month remains significant at the 5 percent level. The result for death by 1 year is no longer significant at conventional levels but remains similar in magnitude to the marginal effect from the Probit estimation. However, because this coefficient becomes statistically weaker when fixed effects are included, this change suggests that the harmful effects of the famine on infants may begin to fade slightly as they become older. Although not presented in the paper, the controls in the regressions have expected signs. For instance, mother's age at birth is negatively correlated with mortality within 1 month of birth, and children who were reported as being smaller than average at birth have a higher likelihood of mortality.

To test whether our results are spurious, we conduct two sets of placebo tests. We estimate equations (1) and (2) using the same outcomes as the previous regressions, but redefining the treatment and sample around the years 1964 and 1984. Neither of those years

[13] This type of selection implies that women who choose to become pregnant during a Famine are negatively selected. Based on observable measures, the descriptive statistics from Table 1b suggest the opposite; though the magnitude of the difference is not large, women who became pregnant during the famine were more educated and married spouses who were more educated, compared to women who avoided pregnancy.

were affected by famine, war, monsoon, or other catastrophic events.[14]

The results of these experiments are presented in Table 2. We find no significant difference between the likelihood of a male birth in the placebo treated year compared to the other birth years in the samples. In addition, estimates from the infant mortality regressions remain small and insignificant, further supporting our findings that the 1974-75 famine is the driving factor behind the increased infant mortaility observed in our main results.

Because previous studies have shown that males are less likely to survive *in utero* when exposed to malnutrition than females (Almond et al. 2010), Table 3 presents infant mortality results separately for male and female infants. Consistent with these studies, the coefficient estimates suggest that the results from Table 2 are in fact driven by male mortality. The marginal effects on male infants in columns 2 and 8 imply that those who were exposed to the Famine *in utero* were 3-4 percent more likely to die within the first month or year after birth. The fixed effects estimates in columns 3 and 9 confirm these results. Female infants, on the other hand, do not have significantly different survival rates associated with famine exposure. The estimates using 1964 or 1984 as placebo famine years do not indicate any positive relationship with infant mortality rates.[15]

Table 4 varies the window of treatment in order to better understand the impact of exposure to malnutrition through the different stages of pregnancy. The first row repeats the main results from Table 2, while the second and third rows alter the length of the treatment, effectively increasing the amount of time the infant is exposed to the famine while in utero.

[14] The sample for the 1964 placebo test includes births between 1960 and 1970. For the 1984 placebo test, the sample includes births between 1980 and 1990.

[15] In the 1964 and 1984 placebo tests, we find that female infants born in these years were less likely to die within one month of birth. There is no evidence, however, that mortality rates increase in either of the Famine placebo years.

The treatment window of births between December 1974 and September 1975 means that the child would have been exposed to the famine for the full third trimester and at least one month of the second trimester. The treatment window of April 1975 through October 1975 means that the child would have been exposed to the famine during his entire nine months *in utero*. The results from Table 4 indicate that as the time of exposure to famine lengthens, the adverse impacts of malnutrition become worse; the marginal effects for infant mortality at both one month and one year become larger in magnitude. Moreover, the likelihood of a male birth becomes larger, more negative, and statistically significant as the time of exposure increases. Thus, male fetuses appear to be especially vulnerable to malnutrition during their first and second trimesters *in utero*.

The final row of Table 4 allows infants with shorter terms of famine exposure to be assigned to the treatment window. This window encompasses all children who experienced at least one month of the famine while in utero, and thus were born between September 1974 and May 1976. The results remain quantitatively similar to other treatment windows. Taken together, the results of Tables 2-4 suggest that famine exposure significantly increases the likelihood of infant mortality, particularly by one month, and most strongly among male infants. However, the adverse effects of the famine appear to fade somewhat as the child reaches one year of age, since the famine coefficients on the likelihood of death by one year are not always as statistically strong.

4.2 Pregnancy Outcomes

The previous estimations focused on the effect of the famine on children *in utero*. However, a famine pregnancy could also affect the mother. The next regressions estimate how experiencing a pregnancy after famine exposure is related to women's long-term fertility outcomes. Table 5 shows the results of estimating equation (3) on women who became pregnant after experiencing at least 9 months of the Famine, compared to other women who were fertile at the time but not pregnant. We find no evidence of a relationship between exposure to Famine and future miscarriages. However, the results suggest that becoming pregnant after exposure to famine increases the likelihood of a stillbirth by about 2 percent (column 4). Since it is possible to identify the gender of a stillborn child, we estimate the number of stillbirths separately for male and female stillbirths. Though future female stillbirths are more common among women who became pregnant during exposure to Famine, this difference is not significant. In contrast, male stillbirths are significantly more common among these women.

In a culture that prefers male children, it could be the case that this difference is driven by a bias in recall: male stillbirths may be more often remembered than female ones.[16] To alleviate this concern, we estimate the same regression using placebo famines in 1965 and 1985, finding no evidence of an increased likelihood of male stillbirth among these cohorts.

To check the sensitivity of the results to the treatment window chosen in Table 5, Table 6 presents estimates of equation (3) where we vary the definition of exposure to the Famine. The first row repeats the original specification from Table 5 in the first row, where women

[16] It is important to note that even if this is the case, there is no reason to believe that this intentional recall bias would vary systematically according to whether a woman was pregnant during the Famine.

have been exposed to at least 9 months of the Famine before becoming pregnant, and still became pregnant before the Famine ends. The next two rows follow the same rule that the woman must become pregnant before the the Famine is over, but reduces the Famine exposure to 6 months, while the third row reduces the exposure to the Famine to 3 months. The effect of famine on future stillbirths is consistently significant at the 1 or 5 percent level, with a marginal effect around 2 percent. Moreover, this effect becomes stronger when the fetus is male. For purposes of comparison, the last row of Table 6 restricts the treatment to the same window used for infants in Table 2. This window does not generate significant results, which suggests that malnutrition due to famine may take longer to affect adults than children. This result is consistent with the medical literature on malnutrition among adults (Collins 1995; Davis 1996).

5 Conclusion

This paper takes advantage of a unique natural experiment, the 1974 Bangladesh Famine, to investigate the relationship between intrauterine malnutrition and key outcomes for infants and mothers. Specifically, we investigate the relationship between intrauterine malnutrition and sex ratio at birth. Previous research on mammals has documented that malnutrition *in utero* decreases the male-to-female sex ratio at birth (Huck et al. 1986) but the impact of malnutrition *in utero* on humans has thus far been documented only among surviving cohorts (Almond et al. 2007). Although the results vary in statistical significance, our analysis using cohorts at birth suggests that malnutrition *in utero* decreases the probability of a male birth, particularly for infants exposed during the first and second trimesters of pregnancy.

We also provide strong evidence that *in utero* exposure to the Famine increases the probability of infant mortality within one month or one year of birth. Importantly, the increase in infant mortality appears to be driven by excess mortality rates among male infants, which suggests that males may continue to be more vulnerable to negative shocks than females for an extended period after birth. This increased rate of male mortality after birth is likely contributing to previous findings in the economics literature on skewed adult male-to-female sex ratios following exposure to *in utero* shocks (Almond et al. 2007).

Because our data also allows us to observe the entire fertility history of women both before and after the Famine, we further investigate whether exposure to the Famine during pregnancy impacts the probability of post-Famine miscarriages or stillbirths, while controlling for pre-Famine fertility. To our knowledge, this is the first study to examine this question. We find that exposure to the Famine during pregnancy is associated with an increase in the probability of having a stillbirth in a future pregnancy, and this effect is particularly pronounced for male stillbirths.

Thus, the results of this paper suggest that malnutrition during famine is likely to have an especially adverse effect on both male infants and pregnant women. These impacts may be long-lasting, as they appear to affect women not only in their current pregnancy, but in their future pregnancies as well. An important area for future research may be to explore the scientific mechanisms through which malnutrition impacts infant mortality rates and future fertility outcomes. Understanding the importance of different channels, whether biological or behavioral, would provide insight into whether these impacts are treatable, thereby providing guidance on how best to target aid after episodes of famine in developing countries.

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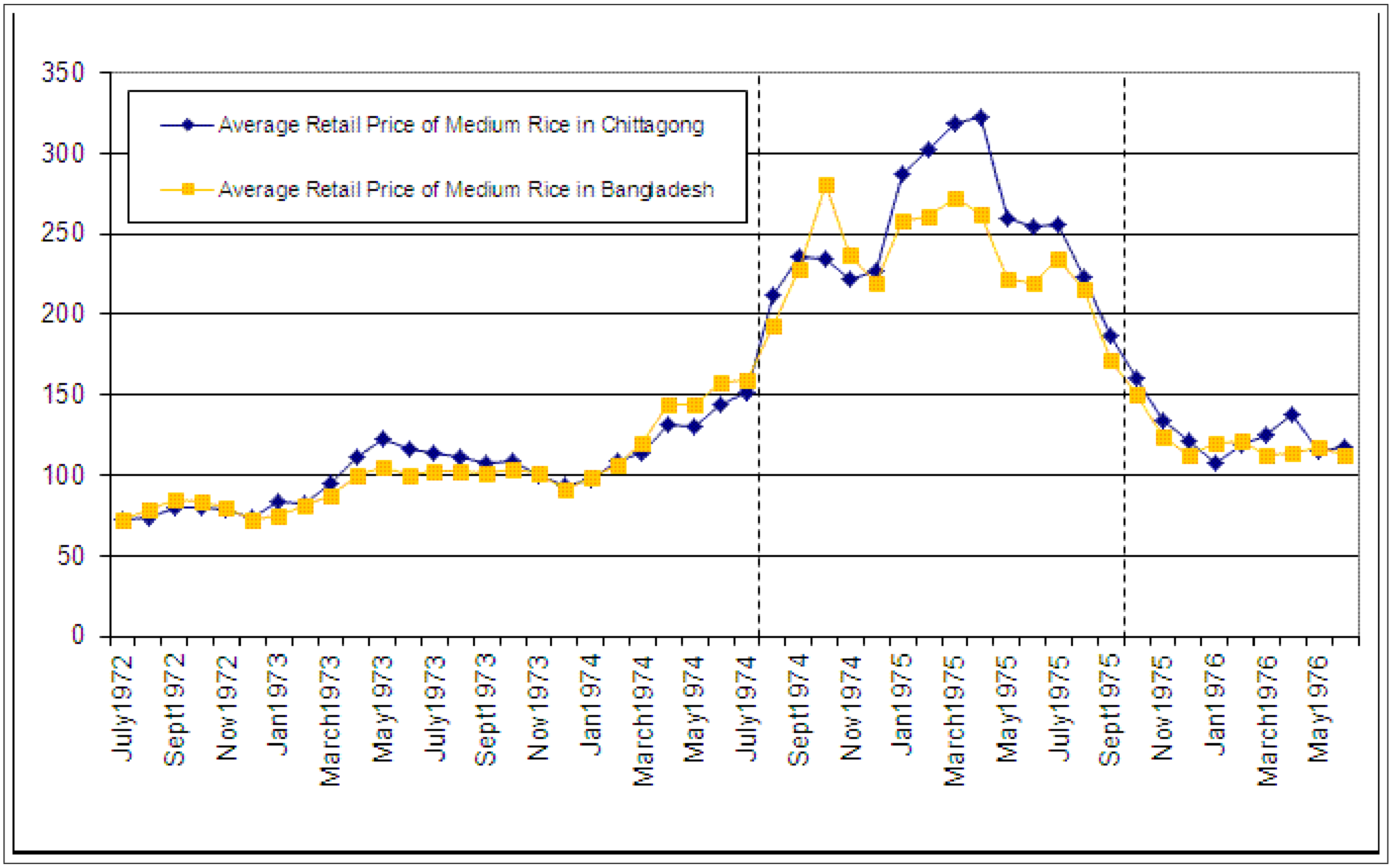

Figure 1: Average retail price of medium rice

Table 1a. Descriptive statistics on the children

Child Outcome	Born during Famine	N	Born in Other Years	N	Difference
Male	0.53	544	0.55	4,544	-0.02
	(0.50)		(0.50)		(0.02)
Death by 1 month	0.08	638	0.06	5,563	**0.02****
	(0.27)		(0.23)		**(0.01)**
Death by 1 year	0.13	638	0.10	5,563	**0.02***
	(0.33)		(0.30)		**(0.01)**
Mother's Education	1.44	544	1.36	4,544	0.08
	(2.47)		(2.36)		(0.11)
Mother's Age at	14.36	544	14.23	4,544	0.13
First Marriage	(4.67)		(3.39)		(0.16)
Mother's Age	25.75	544	26.23	4,544	-0.49
when Child born	(6.77)		(7.04)		(0.32)
Mother's adult	148.73	544	148.85	4,544	-0.12
height (cm)	(5.96)		(6.01)		(0.27)
Number of older	1.60	544	1.59	4,544	0.02
brothers	(1.55)		(1.59)		(0.07)
Number of older	1.46	544	1.48	4,544	-0.02
sisters	(1.50)		(1.49)		(0.07)

Standard deviations in parentheses for means. Standard error in parentheses for the difference.

Child outcomes include all live births 1970-1980. "Born during famine" = born between September 1974 and December 1975. * Statistically significant at the 0.10 level; **statistically significant at the 0.05 level; *** statistically significant at the 0.01 level.

The number of older brothers and sisters include only live births.

Table 1b. Descriptive statistics on the mothers					
Maternal Outcomes	Experienced Famine Pregnancy	N	No experience of Famine Pregnancy	N	Difference
Post-Famine Pregnancy	0.06	712	0.06	4,760	-0.01
resulted in Miscarriage	(0.23)		(0.25)		(0.01)
Post-Famine Pregnancy	0.05	712	0.03	4,760	**0.02***
resulted in Stillbirth	(0.54)		(0.54)		**(0.02)**
Post-Famine Pregnancy	0.06	356	0.03	2,204	**0.03***
resulted in Male Stillbirth	(0.24)		(0.17)		**(0.01)**
Post-Famine Pregnancy	0.05	356	0.03	2,556	**0.02** *
resulted in Female Stillbirth	(0.21)		(0.17)		**(0.01)**
Years of Education	1.88	712	1.31	2,760	**0.57***
	(2.70)		(2.34)		**(0.10)**
Age at First Marriage	14.53	712	14.46	2,760	0.07
	(2.29)		(3.35)		(0.13)
Age when Child born	26.73	712	27.35	2,760	**-0.62** **
	(6.69)		(6.97)		**(0.28)**
Spouse's Educ. (yrs)	4.13	712	3.52	2,760	**0.61***
	(4.18)		(3.88)		**(0.16)**
Adult height (cm)	148.92	712	149.18	2,760	-0.26
	(5.36)		(6.13)		(0.24)
Number of sons	1.01	712	0.91	2,760	**0.61***
born before Famine	(1.27)		(1.21)		**(0.16)**
Number of daughters	0.82	712	0.74	2,760	**0.10** **
born before Famine	(1.02)		(1.14)		**(0.05)**
Number of sons	1.91	712	1.99	2,760	-0.08
born after Famine	(1.50)		(1.36)		(0.06)
Number of Daughters	1.80	712	1.98	2,760	**-0.18***
born after Famine	(1.31)		(1.43)		**(0.06)**

Standard deviations in parentheses for means. Standard error in parentheses for the difference.

"Famine Pregnancy"= birth outcome (live, stillbirth, or miscarriage) between January 1976- July 1976.

*Statistically significant at the 0.10 level; **statistically significant at the 0.05 level; *** statistically significant at the 0.01 level.

The number of older brothers and sisters include only live births.

Table 2. Impact of Famine on sex ratio and infant mortality

	Likelihood of male birth			Death by 1 month			Death by 1 year		
	(1) Probit	(2) m.e.	(3) f.e.	(4) Probit	(5) m.e.	(6) f.e.	(7) Probit	(8) m.e.	(9) f.e.
Sept 1974 - Dec 1975 birth	-0.05	-0.02	-0.03	**0.19****	**0.02**	**0.03****	**0.13***	**0.02**	0.02
(1970-1980 cohorts)	(0.06)		(0.02)	**(0.08)**		**(0.01)**	**(0.07)**		(0.02)
N	5,088		4,484	6,201		5,652	6,201		5,652
Placebo years:									
1964 "Famine " birth	-0.04	-0.02	-0.04	-0.10	-0.01	-0.01	-0.08	-0.01	-0.02
(1960-1970 cohorts)	(0.08)		(0.03)	(0.01)		(0.01)	(0.08)		(0.02)
. N	2,992		2,521	4,853		4,502	4,853		4,502
1984 "Famine" birth	-0.00	-0.00	-0.01	-0.05	0.00	-0.01	-0.12	-0.02	-0.01
(1980-1990 cohorts)	(0.05)		(0.02)	(0.09)		(0.01)	(0.08)		(0.01)
N	6,066		5,311	6,420		5,675	6,420		5,675

*Statistically significant at the 0.10 level; **statistically significant at the 0.05 level; *** statistically significant at the 0.01 level. "Famine birth" means born between September 1974 and December 1975. Standard errors corrected for clustering at the Bari level are in parentheses. Marginal effects, labeled m.e., are evaluated at the mean. Regressions labeled f.e. include mother fixed effects.

All regressions include controls for year of birth linear trend, mother's education, age at marriage age at birth, age at birth squared, height in 1996, number of older brothers and sisters, indicators for size at birth, indicators for season at birth, and an indicator for whether the mother's village is in the treatment group of a Maternal and Child Health Planning services program.

Table 3. Impact of Famine on infant mortality, by gender

	Death by 1 month						Death by 1 year					
	Male			Female			Male			Female		
	(1) Probit	(2) m.e.	(3) f.e.	(4) Probit	(5) m.e.	(6) f.e.	(7) Probit	(8) m.e.	(9) f.e.	(10) Probit	(11) m.e.	(12) f.e.
Sept 1974 - Dec 1975 birth	**0.31*****	**0.04**	**0.05*****	0.06	0.01	0.02	**0.19***	**0.03**	**0.04***	0.08	0.01	0.02
(1970-1980 cohorts)	**(0.104)**		**(0.02)**	(0.12)		(0.02)	**(0.11)**		**(0.02)**	(0.10)		(0.03)
N	3,236		2,296	2,965		2,068	3,236		2,296	2,965		2,068
Placebo years:												
1964 "Famine" birth	-0.02	0.00	-0.00	-0.23	-0.02	**-0.06*****	-0.09	-0.02	-0.01	-0.09	-0.02	-0.05
(1960-1970 cohorts)	(0.13)		(0.02)	(0.17)		**(0.02)**	(0.12)		(0.03)	(0.12)		(0.03)
N	2,534		1,894	2,319		1,757	2,534		1,894	2,319		1,757
1984 "Famine" birth	0.07	0.01	0.01	-0.19	-0.01	**-0.03****	-0.10	-0.01	0.00	-0.13	-0.02	-0.03
(1980-1990 cohorts)	(0.11)		(0.02)	(0.12)		**(0.02)**	(0.11)		(0.02)	(0.09)		(0.02)
N	3,269		2,115	3,151		2,074	3,269		2,115	3,151		2,074

*Statistically significant at the 0.10 level; **statistically significant at the 0.05 level; *** statistically significant at the 0.01 level. "Famine birth" means born between September 1974 and December 1975. Standard errors corrected for clustering at the Bari level are in parentheses. Marginal effects evaluated at the mean are reported in columns 2, 4, 6, and 8. See notes to Table 2 for list of controls.

Table 4. Impact of Famine on sex ratio and infant mortality: Alternative measures of exposure

	Likelihood of male birth			Death by 1 month			Death by 1 year		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Probit	m.e.	f.e.	Probit	m.e.	f.e.	Probit	m.e.	f.e.
Born Sept 74- Dec 75	-0.05	-0.02	-0.03	**0.19****	**0.02**	**0.03****	**0.13***	**0.02**	0.02
	(0.06)		(0.022)	**(0.08)**		**(0.01)**	**(0.07)**		(0.02)
Born Dec 74 - Sep 75	-0.09	-0.04	**-0.06****	**0.25****	**0.03**	**0.03***	**0.18****	**0.04**	0.03
	(0.07)		**(0.03)**	**(0.10)**		**(0.02)**	**(0.09)**		(0.02)
Born April 75 - Oct 75	-0.07	-0.03	**-0.06****	**0.28***	**0.04**	**0.04***	0.14	0.03	0.02
	(0.09)		**(0.03)**	**(0.15)**		**(0.02)**	(0.02)		(0.03)
Born Sept 74 - May 76	-0.05	-0.02	-0.02	**0.20*****	**0.02**	**0.03*****	**0.14****	**0.03**	**0.02***
	(0.05)		(0.02)	**(0.07)**		**(0.01)**	**(0.06)**		**(0.01)**
N	5,088		4,484	6,201		5,652	6,201		5,652

*Statistically significant at the 0.10 level; **statistically significant at the 0.05 level; *** statistically significant at the 0.01 level. Standard errors corrected for clustering at the Bari level are in parentheses. Samples include all births occurred between 1970-1980. Marginal effects evaluated at the mean are reported in columns labeled m.e. Mother fixed effects are included in columns labeled f.e. See notes to Table 2 for list of controls.

Table 5. Impact of Famine on post-Famine pregnancy outcomes

	Miscarriage		Stillbirth		Stillbirth male fetus		Stillbirth female fetus	
	(1) Probit	(2) m.e.	(3) Probit	(4) m.e.	(5) Probit	(6) m.e.	(7) Probit	(8) m.e.
Pregnancy outcome	-0.10	-0.01	**0.27*** **	**0.02**	**0.35*** **	**0.03**	0.20	0.01
Jan 76 - July 76	(0.09)		**(0.01)**		**(0.13)**		(0.14)	
Obs	5,472		5,472		2,560		2,558	
Placebo years:								
Pregnancy outcome	-0.02	-0.00	-0.17	-0.01	-0.11	-0.01	-0.19	-0.01
Jan 66 - July 66	(0.10)		(0.11)		(0.15)		(0.19)	
Obs	5,520		5,502		2,669		2,568	
Pregnancy outcome	0.02	0.00	0.01	0.00	-0.13	-0.01	0.20	0.01
Jan 86 - July 86	(0.10)		(0.12)		(0.18)		(0.17)	
Obs	5,502		3,862		1,785		1,799	

Robust standard errors in parentheses, clustered by bari. *Statistically significant at the 0.10 level; **statistically significant at the 0.05 level; *** statistically significant at the 0.01 level.

Marginal effects evaluated at the mean are reported in columns labeled m.e.

Controls include education, at at first marriage, age at child's birth, age at birth squared, height, indicator for whether mother resides in a treatment group village of a Maternal and Child Health and Family Planning services program, total sons born before famine (live births), total daughters born before famine (live births), spouse's years of education, total sons born after famine (live births), and total daughters born after famine (live births).

Table 6. Impact of Famine on post-Famine pregnancy outcomes: Alternative measures of exposure

	Miscarriage		Stillbirth		Stillbirth male fetus		Stillbirth female fetus	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Probit	m.e.	Probit	m.e.	Probit	m.e.	Probit	m.e.
Preg. outcome Jan 76 - July 76	-0.10	-0.01	**0.27*****	**0.02**	**0.35*****	**0.03**	0.20	0.01
	(0.09)		**(0.01)**		**(0.13)**		(0.14)	
Preg. outcome Oct 75 - July 76	-0.02	-0.00	**0.16****	**0.01**	**0.19***	**0.01**	**0.18***	**0.01**
	(0.06)		**(0.08)**		**(0.11)**		**(0.11)**	
Preg. outcome July 75 - July 76	-0.11	-0.01	**0.22*****	**0.02**	**0.31*****	**0.02**	0.15	0.01
	(0.07)		**(0.08)**		**(0.11)**		(0.12)	
Preg. outcome Sept 74 - Dec 75	0.03	0.00	0.07	0.00	0.12	0.01	0.08	0.00
	(0.07)		(0.08)		(0.12)		(0.11)	
Obs	5,472		5,472		2,560		2,558	

Robust standard errors in parentheses, clustered by bari. *Statistically significant at the 0.10 level; **statistically significant at the 0.05 level; *** statistically significant at the 0.01 level.

Sample: all women fertile during the 1975 famine.

Controls include education, at at first marriage, age at child's birth, age at birth squared, height, indicator for whether mother resides in a treatment group village of a Maternal and Child Health and Family Planning services program, total sons born before famine (live births), total daughters born before famine (live births), spouse's years of education, total sons born after famine (live births), and total daughters born after famine (live births).