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Does Ramadan Harm Infant Health? Evidence from Ethiopia

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ABSTRACT

We examine the impact of religious practices on human capital in the context of Ethiopia. We focus on Ramadan, which leads mothers to reduce nutritional intake during the daytime. By exploiting the variation in the extent to which infants were exposed to Ramadan, we estimate the relative disadvantage of Muslim children compared to their non-Muslim counterparts. We find that the exposure to Ramadan in the first trimester has a significant negative effect on the infants' health outcomes, but not on later life outcomes.

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1. Introduction

Religion is a pervasive and multifaceted social phenomenon that affects various dimensions of individual lives. Religion may affect economic outcomes, as it prescribes a set of rules and norms that believers are required to adhere to. For example, religious practices require a certain level of devotion in terms of time and resources which could have instead been used for production. Religion may shape beliefs and impose restrictions that affect individuals' economic decisions (e.g. prohibiting interests). Not surprisingly, various studies present evidence suggesting that religion may have effects on human capital accumulation. For example, researchers find effects of religious practices on psychological health (e.g. Chiswick & Mirtcheva, 2013), literacy (e.g. Chaudhary & Rubin, 2011), and academic achievement (e.g. Muller & Ellison, 2001).

We examine the impact of religious practices on human capital in the context of Ethiopia. We focus on Ramadan fasting, one of the essential practices in observing Islam, which leads mothers to reduce nutritional intake during the daytime. Several studies have examined the impact of Ramadan on both individual and economy-wide outcomes (e.g.

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infant health, sex ratios, GDP growth rate, and subjective wellbeing).[1] Our paper contributes to this literature by examining an understudied country, namely Ethiopia, and employing an econometric framework to estimate the causal effect of Ramadan on both the health of newborns and their later life outcomes.

Ethiopia provides a suitable setting for researchers to examine the effect of Ramadan. Specifically, existing studies examine the countries where Muslims are either the dominant religious group or the minority. Thus, to identify the causal effect, they rely on either exploiting cross-country variations or comparing the majority with a minority within a country, which can differ in many aspects other than religion.[2] In contrast, in Ethiopia, populations are comparably distributed across major religious groups. In 2007, the population was divided into Ethiopian Orthodox Christianity (44%), Islam (34%), Protestantism (19%), and the rest. Thus, it is more likely for us to examine effects of religion by constructing plausible comparison groups with similar socioeconomic backgrounds, except for religious beliefs.

We estimate the causal effect of Ramadan on children's health outcomes by exploiting three types of variations. First, among Muslims, we compare infants depending on the extent and the time when they were exposed to Ramadan *in utero* longer than their counterparts. If we had only Muslims in our data, we would not be able to distinguish the effect of Ramadan from the effect of conception timing. Thus, second, we use non-Muslim infants conceived at the same time as Muslims to separate out the effect of conception timing. Finally, we exploit the discrepancy between the Islamic and Gregorian calendars to further tease out possible time-varying difference between Muslim and non-Muslim infants. Suppose that, for instance, children conceived in a specific month are more likely to die and Muslims are more likely to conceive a child in that month compared to their Ethiopian Orthodox counterparts. If Ramadan coincides with that month, then we may falsely attribute the effect of the conception month to Ramadan. However, we tease out such a seasonality effect by exploiting the fact that the Islamic calendar, a lunar calendar, does not coincide with Gregorian calendar, and thus the start and end dates of Ramadan vary from year to year. By adding time-fixed effects, we capture possible seasonality effects. Unless Muslim mothers actively choose the timing of conception based on the lunar calendar, the variation we exploit is exogenous to infant health. In our analysis, we show that such behaviors may not be sufficiently prevalent in our setting to invalidate our identification strategy.

[1] Campante and Yanagizawa-Drott (2015) study the effect of Ramadan fasting on economic growth at the country level and on individual wellbeing. To establish causality, they use the variation in the length of daily fasting due to the interaction between the rotating Islamic calendar and a country's latitude. The results show that Ramadan fasting has a negative effect on the growth output in Islamic countries but has a positive effect on subjective wellbeing among Muslims. Almond and Mazumder (2011) find that exposure to Ramadan in the US leads to lower birth weights and fewer males compared to females, and evidence of learning disabilities in Uganda and Iraq, in addition to negative effects on crude wealth measures. Using the Indonesian Family Life Survey data, Van Ewijk (2011) finds that Muslim children exposed to Ramadan have comparatively poorer general health, fewer males compared to females, and symptoms of coronary heart problems and type 2 diabetes in older age.

[2] Almond and Mazumder (2011) exploited data collected from Michigan in the US, and Census data from Uganda and Iraq; Almond et al. (2015) utilized student register data from Pakistani and Bangladeshi families in the UK; Campante and Yanagizawa-Drott (2015) performed a cross-country analysis using variation in the length of daily fasting due to the interaction between the rotating Islamic calendar and a specific latitude.

We use three waves of the Ethiopia Demographic and Health Survey (DHS 2000, 2005, and 2011).[3] Our results show that Ramadan increases mortality among Muslim infants. Compared to Ethiopian Orthodox Christians, Muslim infants who were exposed to Ramadan in the first trimester *in utero* are 2.1%p (43%) more likely to die within three months after birth and 2.7%p (38%) more likely to die within one year after birth. However, we do not find such a systematic change in death rates among newborns of Orthodox Christian or Protestant families, validating our identification assumption. The estimated effect of Ramadan is consistent with the fetal origins hypothesis, in that mother's fasting during the Ramadan period provides an adverse environment for infants *in utero*, deteriorating their health outcomes significantly.[4]

We further examine birth weight, sex ratio, and later life outcomes. Consistent with existing studies (e.g. Almond & Mazumder, 2011; in the US and Van Ewijk, 2011, in Indonesia), we also find a negative effect of Ramadan on birth size, which is highly correlated with birth weight. In our setting, Ramadan exposure increases the probability of being born smaller than average by 3.8%p (12%). However, we do not find a statistically significant effect on birth weight because of a small sample size and possible sample selection. Only 8% of the newborns in our sample report birth weight, and the likelihood of reporting birth weight depends on parental background.

Various studies in biology and economics report the finding that adverse environments may affect the gender composition among newborns, as girls/female fetuses are more robust to such environments (Trivers & Willard, 1973). In fact, Almond and Mazumder (2011) find that exposure to Ramadan in the US leads to fewer males compared to females. In our sample, the effect on sex ratio is not statistically significant. In addition, we examine contemporaneous outcome variables including school enrollment, educational attainment, height, being underweight, and anemia, but we do not find statistically significant effects of Ramadan exposure *in utero*.

Finally, we investigate to what extent Muslim mothers may time conception in response to Ramadan. It is possible that Muslim mothers are well aware of the negative effects and try to avoid being pregnant during Ramadan, especially the first trimester of pregnancy, through family planning. If so, we may observe a decrease in the number of births among Muslims relative to non-Muslims during Ramadan. However, we do not find any significant changes in the number of Muslim births during Ramadan, especially births which overlap Ramadan in the first trimester. However, we do not find any significant changes in the number of Muslim births during Ramadan.

The remainder of the paper is structured as follows: Section II explains the institutional background in Ethiopia. Section III lays out the empirical framework of the analysis with data descriptions. Section IV presents the results, and Section V presents robustness checks. Section VI concludes the paper.

[3] The actual interviews in each wave of the Ethiopia Demographic and Health Survey happened in 1992, 1997 and 2003 respectively.

[4] Various studies report evidence consistent with the fetal origins hypothesis. For example, Barker (1995) finds that men and women whose birth weights were at the lower end of the normal range, because of undernutrition during gestation, have increased rates of coronary heart diseases. Almond (2006) finds that *in utero* exposure during the 1918 influenza pandemic resulted in reduced educational levels, increased physical disability, and lower socioeconomic status.

Table 1. Distribution of religions by region.

		Religion share (%)			
	No. residents (1)	Orthodox (2)	Islam (3)	Protestant (4)	Others (5)
Addisababa city adm.	2,739,551	74.66	16.21	7.77	1.36
Affar	1,390,273	3.93	95.28	0.67	0.12
Amhara	17,221,976	82.54	17.15	0.18	0.14
Benishangul-Gumuz	784,345	33.3	44.98	13.53	8.2
Diredawa city adm.	341,834	25.66	70.82	2.81	0.71
Gambella	307,096	16.76	4.86	70.09	8.29
Harari	183,415	27.11	68.99	3.45	0.46
Oromia	26,993,933	30.4	47.55	17.71	4.34
S.N.N.*P*	14,929,548	19.86	14.12	55.48	10.55
Somali	4,445,219	0.63	98.42	0.06	0.89
Tigray	4,316,988	95.56	3.96	0.08	0.39
Total	73,654,178	43.57	33.87	18.55	4.02

Notes: Authors' calculation. Source: Ethiopia Central Statistical Agency (2008). We exclude individuals residing in national parks, forest reserves, and collective living quarters (e.g. boarding schools, university dormitories, police camps, correctional facilities, orphanages, and hospitals). These residents are referred to as 'Special Enumeration Areas' in the Ethiopia Census. In 2007, the number of residents in such areas was only 96,754 (0.13 percent).

2. Institutional Background

2.1. Religions in Ethiopia

The Ethiopian constitution of 1995 provides freedom of religion and requires the separation of state and religion. The government seeks to protect this right in full and does not tolerate its abuse, either by governmental or private actors. According to the national census conducted in 2007, the largest faiths are Ethiopian Orthodox Christianity and Islam, while there exists great variation across geographical areas and ethnicities (Ethiopia Central Statistical Agency, 2008). See Figure 1 and Table 1. The Ethiopian Orthodox Church accounts for 44% of the population, predominant in Amhara and Tigray, located in the Northwest part of the country. Sunni Muslims account for 34%, prevalent in Northeast regions such as Afar and Somali. Protestants occupy the third place in the religious scene, accounting for 19% of the population. In the Southwest regions such as Gambella and S.N.N.P (Southern Nations, Nationalities, and Peoples), the majority of residents follow Protestant Christianity. The remaining religious groups classified as 'others' in Table 1 include Roman Catholics, Jehovah's Witnesses, Jews, Mormons, animists, and practitioners of indigenous religions.

It is worth highlighting that most regions in Ethiopia have both Ethiopian Orthodox and Islam as major religious groups among their residents. For example, in 7 out of 11 regions, the share of the Ethiopian Orthodox among residents is over 10% while the share of Islam is also over 10%. In our empirical framework, discussed in Section III.2, we exploit within-region variations across religious groups to examine the effect of Ramadan, as well as controlling for other explanatory variables.

2.2. Ramadan

Islam, one of the most practiced religions in Ethiopia, prescribes strict sets of rules and practices that constrain its followers. Ramadan fasting is a very prominent example of

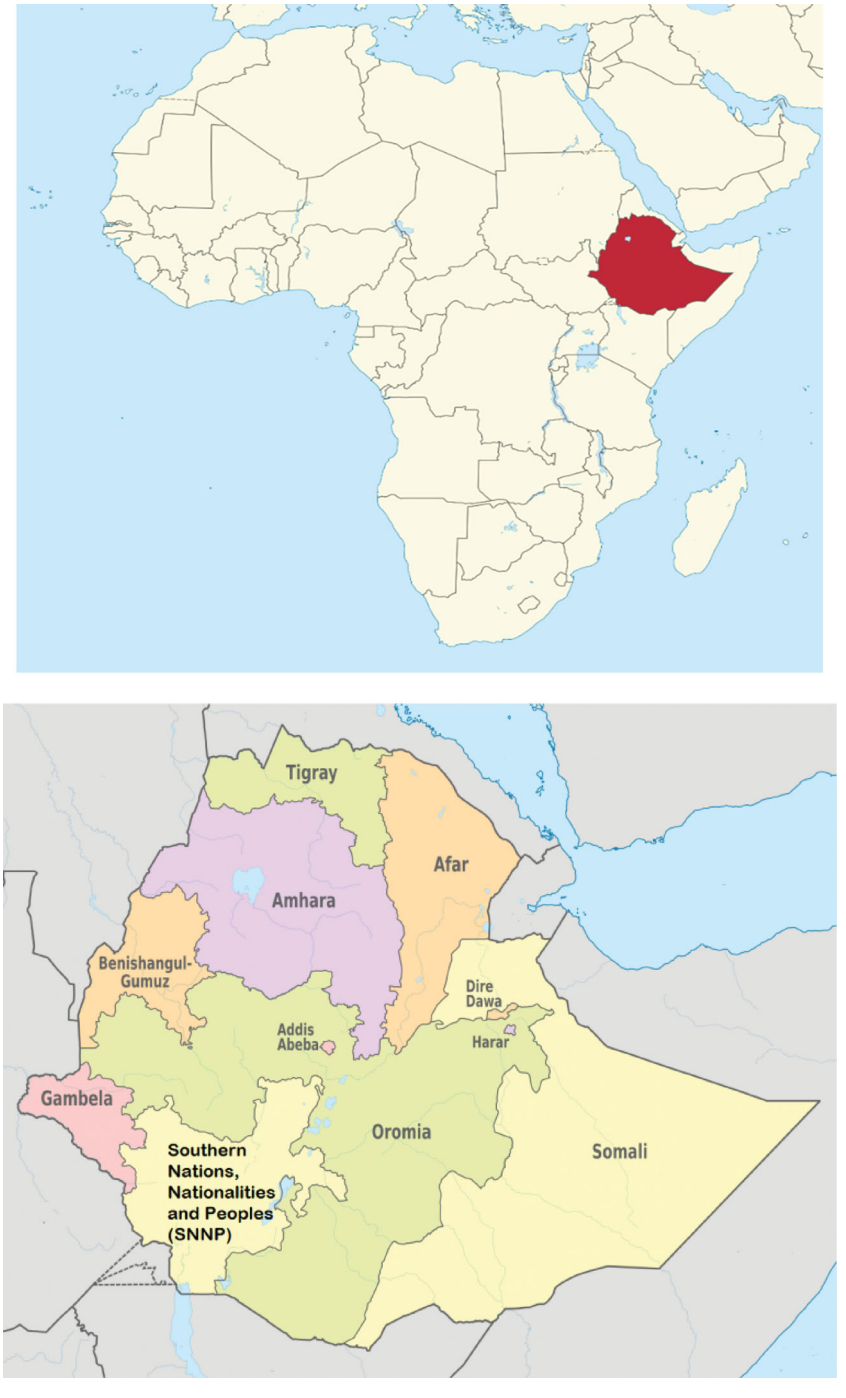

Figure 1. Map of Ethiopia. Reference: (Top Figure) https://commons.wikimedia.org/wiki/File:Ethiopia_in_Africa_(-mini_map_-rivers).svg#file; (Bottom Figure) https://www.outlookethiopia.com/news/21-opinion/822-regional-autonomy-is-a-viral-catch-22-final-part-2.

such a practice. Ramadan, the ninth month of the Islamic calendar, is considered sacred as the month in which the Prophet Muhammad first received revelation. Fasting during that month is one of the Five Pillars of Islam. The fasting involves abstention from food and drink, as well as smoking and sexual activities, between dawn and sunset during the entire month. Ramadan fasting entails obvious physiological consequences because of the constraints it places on the ingestion of food and liquids, and these consequences have been extensively studied in the medical literature. More broadly, the daily routine incorporates predawn and fast-breaking meals, and other major social events involving family, friends, and acquaintances.

Following Ramadan practices may incur physiological stress and negative health effects as a result, possibly due to lack of food and drink as well as interfering in natural sleep cycles so as to be awake earlier for predawn meals and stay awake later for late dinners and other social events. Indeed, this conjecture has been found to be the case in various settings. Ziaee et al. (2006) find that during Ramadan there are significant metabolic changes. Leiper et al. (2003) report finding symptoms such as irritability, headaches, and sleep deprivation. Pregnant women can request an exception from Ramadan which typically requires them to make up days later. However, fasting during pregnancy remains common today. According to Arab and Nasrollahi (2001), Joosoph et al. (2005), Malhotra et al. (1989), and Prentice et al. (1983), around 70% to 90% of Muslim women around the world, including those in Singapore, Iran, and the United Kingdom, report fasting during pregnancy.

The Islamic calendar, which is lunar, defines the start and end of Ramadan each year. As a year as defined in the Islamic calendar is ten to eleven days shorter than a year as defined in the standard solar calendar, and the time when Ramadan starts rotates across different seasons. To illustrate this point, in 1988 Ramadan started in April, whereas in 2002 it started in November. We exploit the exogenous variation of Ramadan to identify the impact of Ramadan on the health outcomes of children. The validity of our empirical strategy will be discussed in Section III.2.

3. Data and Empirical Framework

3.1. Data

Data Source

We use the three waves of the Ethiopia Demographic and Health Survey (DHS 2000, 2005, and 2011), conducted by the Ethiopian Central Statistical Agency and the United States Agency for International Development (USAID). The DHS surveys women of reproductive age (i.e. 15–49 years old) who had given birth to a child to gather information on their household, husband, children, and themselves.

The DHS information on household includes region of residence (whether living in rural or urban areas in 11 regions), ethnicity, and a measure of household wealth. The DHS constructs a wealth index based on ownership of selected assets, such as televisions and bicycles, materials used for housing construction, and types of water access and sanitation facilities.[5] Using the index, DHS categorizes households into 5 groups (poorest, poorer, middle, richer, richest) and we include corresponding indicators as control variables. Women's information includes religion, age, educational attainment, Body Mass

[5] See detailed explanation of the wealth index available at https://www.dhsprogram.com/topics/wealth-index/index.cfm

Index (BMI), occupation, and employment status, while the information on their husbands includes age, educational attainment level, and occupation.[6] The information on occupation is based on a survey participant's usual occupation, even if he/she is currently unemployed or not in the labor force. The DHS classifies occupations into 8 categories (did not work, professional, clerical, sales, agricultural, services, skilled manual, and unskilled manual). In addition, the DHS asks whether a person is currently employed. Children's information (reported by their mothers) includes sex, birth month, birth year, birth order, birth weight, birth size, and the time of death if the children had already passed away at the time of survey.

Sample and Variables

Our baseline sample consists of children whose age would be between 0 and 4 at the time of the survey if the child is alive or would have been alive. As the children's information relies on their mothers' memories, we limit the children's age to 4 years to reduce possible errors in recollection. As the surveys were conducted every 5 years, we observe children only once in our sample. This selection yields 21,425 children and their parents in our sample.

We construct a variable measuring the extent to which the child had been exposed to Ramadan *in utero* as follows. We use the information posted on Islamic Philosophy Online and collect the start and end dates of Ramadan from 1988 (the oldest birth cohort in our sample) to 2003 (the youngest).[7] Assuming a 9-month-long gestation, we calculate the month of conception for each birth using the birth month of a child, and measure whether the child was *in utero* during Ramadan and, if so, when. As the Ethiopia DHS provides only birth month of a child, not date, we regard a child as having been exposed to Ramadan if he/she was *in utero* during the month when Ramadan occurred. Because of this data limitation, we may treat some children as having been exposed to Ramadan even though they were not.[8] Although our approach may not be ideal, it provides a conservative estimate of the effect of Ramadan, due to possible attenuation bias. That is, we include the infants who were not exposed to Ramadan in the treatment group, thus making the estimated effect weaker.

The literature finds that an adverse environment can be particularly harmful to children if they were exposed to the environment during the first trimester (Almond & Mazumder, 2011; Barker, 1995).[9] To incorporate this finding, we construct three indicating variables: whether a child was exposed to Ramadan *in utero* in the first trimester, in the second trimester, and in the third/final trimester. Note that the first trimester is from week 1 to the end of week 12, the second trimester is from week 13 to the end of week 26, and the third trimester is from week 27 to the end of the pregnancy. These variables indicate whether and when a child was exposed to Ramadan. If a child was exposed to Ramadan in

[6] The Ethiopia DHS does not provide the information on fathers' current employment status or religion.

[7] Islamic Philosophy Online follows data provided by Institute of Oriental Studies at Zurich University. See details at http://www.muslimphilosophy.com/ip/hijri.htm.

[8] Consider the following example. In 1988, Ramadan started on April 18 and ended on May 17. For the infants born in April 1988, we treat them as having been exposed to Ramadan in the 3rd trimester even if they were born prior to April 18.

[9] The third through eighth weeks of gestation are called the embryonic stage, during which the embryo develops most major body organs. During this process, the embryo is very vulnerable to external impacts, so the impact of Ramadan exposure in the first trimester of pregnancy is expected to be greater than that in other periods. Thus, the time during which a child is exposed to Ramadan may be crucial in comparing infant mortality and birth weight.

two trimesters, we choose the trimester for which the Ramadan overlap was longer.[10] As a result, those three variables are mutually exclusive.

Our baseline analysis examines three types of infant's health outcome: mortality, birth weight, and size. For mortality, we use three variables: death at birth, death within three months, and death within one year. All are binary variables which take the value 1 if the child died within each period. For birth weight, we use both birth weight and the indicator of whether an infant is underweight (i.e. birth weight less than 2,500 grams). Unfortunately, only 8% of children (1,633 out of 21,425 children) in our sample report birth weight. To address possible sample selection bias, we examine another variable, a child's size at birth, to approximate whether the child is underweight. The DHS asks mothers how large their children were at birth, out of 5 categories: very small, small, average, large, very large. This information is much more available in our sample (99.95%). We create another variable that is 1 if a child's reported size is either very small or small, which accounts for 32%. This alternative variable is strongly correlated with whether a child weighed less than 2,500 grams at birth.[11]

Summary Statistics

Panels A and B in Table 2 report summary statistics of parents and children, respectively. The table shows that, in general, the parents in our sample work in the agricultural sector, with no formal education. Mothers of newborns were on average 27 years old when they gave birth, and there exists little difference across religions. There are 61 ethnicities reported in our sample, but 73% of mothers belong to the 5 major ethnic groups in Ethiopia (Oromo, Amhara, Somalie, Tigrie, Sidama). The average BMI of the mothers in our sample is 20.29, considered normal, while indices are comparable across religions.[12] However, the share of mothers who are underweight is highest among Muslims (28%) and lowest among Orthodox Christians (23%).

Muslim mothers show a lower level of schooling attainment compared to Orthodox and Protestant mothers. Most mothers (76%) have no formal education at all, while the share is the highest among Muslim mothers (84%), followed by mothers of other religions (81%), Orthodox mothers (71%), and Protestant mothers (63%). The share of mothers who attended primary school, not secondary school, is highest among Protestants (32%), followed by Orthodox Christians (18%), and then Muslims (14%). The share of mothers who attended secondary school is highest among Orthodox Christians (11%). Most of the Muslim mothers were currently not working (71%) and usually did not work (66%) in the past as well. However, Orthodox mothers were more likely to work: 64% of them had usual

[10] Consider a child born in July 1989. Assuming a nine-month gestation, this child would have been conceived in November 1988. Thus, the first, second, and third trimesters cover November 1988 to January 1999, February to April, and May to July 1989, respectively. As Ramadan lasted from April 7, 1989 to May 6, 1989, the child had been exposed to Ramadan *in utero* in the second trimester for 24 days, and in the third trimester for 6 days. As Ramadan exposure is longer during the second trimester compared to the third, we regard this child as having been exposed during the second trimester.

[11] In the sample of those who report both birth weight and size (total of 1,631), the Chi-squared test examining whether the variable of being underweight at birth and the alternative variable based on size at birth rejects the null hypothesis (i.e. independence of the two variables) at the 1% level (test-statistics: 215, *p*-value:0.00). Among those who are underweight in our data, 57% were recorded as smaller than average or very small in term of birth size. Relatedly, among those who are not underweighted in our data, 12% were recorded as being smaller than average or very small. (i.e. the false classification rate is 15%).

[12] According to the US Centers for Disease Control, a BMI between 18.5 and 24.9 indicates a normal or healthy body weight. See https://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/index.html

Table 2. Summary statistics.

Panel A. Parents

		Mother's religion			
	All (1)	Muslim (2)	Orthodox (3)	Protestant (4)	Others (5)
No of observations	21,425	9,744	7,770	3,311	600
Mothers					
Age	26.81	26.68	27.00	26.70	27.18
Schooling					
No education	0.76	0.84	0.71	0.63	0.81
Primary	0.18	0.14	0.18	0.32	0.17
Secondary or more	0.06	0.02	0.11	0.05	0.03
BMI	20.29	20.23	20.44	20.22	19.83
Underweight	0.25	0.28	0.23	0.24	0.27
Obese	0.05	0.05	0.05	0.04	0.04
Occupation					
Not work	0.53	0.66	0.36	0.56	0.45
Agricultural	0.28	0.18	0.43	0.22	0.31
Sales	0.11	0.12	0.09	0.14	0.12
Skilled manual	0.05	0.03	0.06	0.07	0.10
Currently employed	0.36	0.29	0.46	0.35	0.46
Ethnicity					
Oromo	0.29	0.43	0.16	0.23	0.32
Amhara	0.21	0.10	0.45	0.03	0.03
Somalie	0.08	0.18	0.00	0.00	0.01
Tigrie	0.11	0.01	0.28	0.00	0.01
Sidama	0.03	0.00	0.00	0.18	0.11
Others	0.27	0.28	0.12	0.56	0.53
Fathers					
Age	35.25	35.52	35.42	33.78	36.56
Schooling					
No education	0.59	0.70	0.56	0.34	0.58
Primary	0.29	0.24	0.28	0.49	0.32
Secondary or more	0.12	0.06	0.16	0.18	0.10
Occupation					
Not work	0.01	0.02	0.00	0.02	0.01
Agricultural	0.77	0.78	0.73	0.80	0.89
Professional/Technical	0.04	0.03	0.04	0.05	0.02
Sales	0.08	0.10	0.08	0.08	0.04
Skilled manual	0.05	0.04	0.07	0.03	0.02

Notes: Occupations are classified into 8 categories (did not work, professional, clerical, sales, agricultural, services, skilled manual, and unskilled manual). The occupational information refers to the types of jobs individuals usually work in, regardless of current employment status. The information on whether a person is currently employed is only available for mothers, not for fathers.

Panel B. Children

		Mother's religion			
	All (1)	Muslim (2)	Orthodox (3)	Protestant (4)	Others (5)
No of observations	21,425	9,744	7,770	3,311	600
Ramadan Exposure					
Ever exposed (%)	86.24	86.90	85.78	85.41	86.00
Exposed at T1 (%)	26.39	24.65	28.16	27.24	27.17
Exposed at T2 (%)	27.61	27.89	26.92	28.33	28.00
Exposed at T3 (%)	32.23	34.36	30.69	29.84	30.83
1 if dead less than 1 day (%)	1.18	1.20	1.13	1.12	1.67
1 if dead less than 3 months (%)	4.86	4.71	5.12	4.44	6.33
Among those exposed at T1	5.31	6.12	4.75	4.32	6.13

(*continued*).

Table 2. Continued.

Panel B. Children

		Mother's religion			
	All (1)	Muslim (2)	Orthodox (3)	Protestant (4)	Others (5)
1 if dead less than 1 year (%)	7.11	7.28	7.09	6.40	8.50
Among those exposed at T1	7.73	9.28	6.81	5.54	9.20
Birth weight (*grams*)	3,298	3,353	3,261	3,349	3,093
Underweight					
1 if birth weight $<$ 2500 gram	0.10	0.11	0.09	0.11	0.15
1 if birth size is below average	0.32	0.35	0.32	0.25	0.28
Share of Girls	0.49	0.48	0.49	0.49	0.50
Age	2.17	2.16	2.18	2.17	2.24
Birth order					
1st	0.18	0.17	0.20	0.18	0.17
2nd	0.17	0.16	0.18	0.17	0.15
3rd	0.14	0.14	0.15	0.15	0.14
4th	0.12	0.12	0.12	0.13	0.11
5th	0.11	0.11	0.10	0.12	0.11
Above 5th	0.28	0.29	0.26	0.26	0.32
Rural households	0.85	0.87	0.79	0.91	0.96
Household wealth					
Poorest	0.26	0.30	0.20	0.28	0.36
Poorer	0.19	0.17	0.19	0.20	0.21
Middle	0.19	0.18	0.19	0.19	0.23
Richer	0.18	0.18	0.18	0.19	0.15
Richest	0.19	0.17	0.25	0.13	0.06

Notes: If the timing of Ramadan exposure *in utero* overlaps two trimesters, then we choose the trimester in which the Ramadan overlap is longer. We use two variables to measure whether an infant is underweight. The first is whether a child's birth weight was below 2,500 grams, following the standard by the World Health Organization ('1 if birth weight $<$ 2500 gram' in the table). The other variable is based on mother's reports of children's birth size. A child's birth size is classified into 5 categories (very small, small, average, large, very large). We construct the second variable (1 if the child was born 'smaller than average' or 'very small') to approximate whether a child is underweight. See details in Section III.1 in the main text.

jobs, and more than two-thirds (68% of Orthodox mothers who usually have jobs) had jobs in agricultural sector.

The fathers in our sample were on average 35 years old when the child was born. Approximately 59% of fathers did not attend primary school at all, and there exist great variations across religions. Specifically, among the Protestant households, 18% of fathers attended secondary school, 49% of them attended primary school but not secondary school, and the remaining 34% had no formal education at all. In contrast, among Muslim households, only 6% of fathers attended secondary school, while 70% of them had no formal schooling at all. However, there exist no differences in terms of fathers' occupations, as most of them (77%) are farmers.

Panel B in Table 2 shows the summary statistics from the child data. Among the 9,744 children from Muslim households, 87% were exposed to Ramadan *in utero*. Approximately 25% of Muslim children were exposed to Ramadan in the first trimester of pregnancy, 28% in the second trimester, and 34% in the last trimester. The chance of death within three months, and one year, are on average 4.86% and 7.11% respectively, while slightly more Muslim children passed away within one year (7.28%) compared to Orthodox children (7.09%). Orthodox children, however, have a higher probability of death within three months (5.12%) relative to Muslims (4.71%).

The birthweight of children in our sample is on average 3,298 grams, where Muslim children (3,353 grams) are marginally heavier than Orthodox children (3,261 grams). However, the share of children who were born underweight is larger for Muslim children (11%), than Orthodox children (9%), and this relationship is same with the birth size variable. Because only 8% of our newborns report birth weights, we use another variable, birth size, to approximate a newborn's health regarding birth weight. Specifically, we rely on the information on a child's birth size reported by his or her mother, which is available for almost all children (i.e. 21,416 out of 21,425 observations).

The DHS provides information on birth size, recorded in 5 categories – very large, larger than average, average, smaller than average, very small. We create three alternative underweight variables and calculate Chi-squared test statistics testing whether each of the three variables is independent of the actual underweight indicator using the sample of children who report both birth weight and size. The classification of children whose birth sizes are either smaller than average or very small as being underweight yields the largest test statistic. As a result, we use that classification to examine the health risks associated with birth weight. The fraction of newborns whose size is below average is 32% in our sample, highest among Muslims (35%), followed by Orthodox Christians (32%), and Protestants (25%).

The share of girls among newborns is comparable across religions. The average age of children at the time of survey is 2.17, and over 28% of them have 4 or more older siblings. Approximately 85% of children reside in rural areas. As for household income, the proportions of moderate-income groups (i.e. poorer, middle, and richer group) are close across religions. However, the fraction of the poorest group is highest among Muslims (30%), relative to Orthodox Christians (20%), while the share of the richest group is highest among Orthodox children (25%) and the lowest among Muslim children (only 17%).

3.2. Empirical Framework

We use the following Probit regression model to estimate the effect of Ramadan on binary outcome variables:

$$Y_{i,r,t,l} = 1 \text{ if } Y^*_{i,r,t,l} > 0 \text{ and } 0 \text{ otherwise.} \tag{1}$$

where

$$Y^*_{i,r,t,l} = \alpha + \sum_{j=1}^{3} \beta_j 1(\text{Ramadan at } T_j) + \delta_r 1(\text{Religion } r) + \sum_{j=1}^{3} \gamma_{j,r} 1(\text{Ramadan at } T_j) \times 1(\text{Religion } r) + \mu \mathbf{X}_i + \theta_t + \rho_l + \varepsilon_{i,r,t,l}.$$

Variable $Y_{i,r,t,l}$ is the binary outcome for child i born at time t whose mother has religion r out of 4 groups (Muslim, Ethiopian Orthodox Christian, Protestant, and Others) and resides in location l out of 11 regions. The latent variable $Y^*_{i,r,t,l}$ is a linear function of whether the child was exposed to Ramadan *in utero* during a given trimester (i.e. $1(\text{Ramadan at} T_j)$ with $j \in \{1, 2, 3\}$), religion fixed effects (δ_r), the interaction terms with the Ramadan variables by religion (i.e. $1(\text{Ramadan at} T_j) \times 1(\text{Religion} r)$), observable characteristics ($\mathbf{X}_i$), time effects (θ_t) captured by birth month dummies as well as birth year

dummies, location fixed effects (ρ_l) and random shocks ($\varepsilon_{i,r,t,l}$). We cluster $\varepsilon_{i,r,t,l}$ at the regional level to allow for the possibility that infants residing in the same location may be exposed to common random shocks.

Observable characteristics $\boldsymbol{X}_i$ is a vector of covariates to capture other factors affecting outcome variables, including information on households (indicators of household wealth status categories, residents of rural areas), on parents (age, education level, occupation, and mother's ethnicity, BMI, and current employment status), and on children (indicators of birth order and gender).

We use Ethiopian Orthodox as an omitted category for religions, which is the second-largest religious group (36%) after Muslim (45%). Hence, our parameters of interest are the coefficients of $\gamma_{j,r}$with r being Muslim, which represents the impact on Muslim children who were exposed to Ramadan in the j^{th} trimester, relative to an Ethiopian Orthodox child whose gestation overlapped with Ramadan during the same trimester. Our identification assumes that, conditional on religion-, month-, year, and region- fixed effects and other control variables, Ramadan accounts for any systematic differences between Muslim and Orthodox Christian children exposed to it *in utero*. If our assumption holds, then the estimates of $\gamma_{1,r}$, $\gamma_{2,r}$, and $\gamma_{3,r}$ with r being Muslim will measure the effect of Ramadan on children who were exposed to it during the first, second, and third trimester *in utero*, respectively.

For our baseline analysis, we examine four binary outcomes: whether a child passed away within a day of birth, within three months after birth, or within one year after birth, and whether a child is born underweight. In addition, for continuous outcomes (birth weight) we estimate linear regression models, following the specification for the latent variable in equation (1).

3.3. Plausibility of the Identification Strategy

We conduct two types of analysis to examine the plausibility of our identification strategy. The first is based on the outcomes of non-Muslim children exposed to Ramadan, relative to their peers from the same religious group but not exposed to Ramadan. As non-Muslims do not observe Ramadan, there should be no systematic differences between the two groups if we include appropriate control variables.

Consider Ethiopian Orthodox Christians. Like Islam, the Ethiopian Orthodox religion imposes dietary restrictions and has festival days, but these events do not follow the Islamic calendar.[13] Thus, whether and when a child was exposed to Ramadan *in utero* should not account for birth outcomes for Orthodox Christian children, implying that β_j with $j \in \{1, 2, 3\}$, the estimated coefficient of $1(\text{Ramadan at} T_j)$ should be zero. By the same logic,

[13] Ethiopian Orthodox Christians observe strict dietary restrictions. For example, for at least 180 days a year, Orthodox Christians are not to consume any animal products such as meat, eggs, and dairy, and abstain from eating or drinking before 3pm. However, the fasting happens every Wednesday and Friday throughout a year, with some special occasions such as Easter or Christmas. These special occasions follow the Ethiopian calendar that is not identical to, but is very similar to, the Gregorian calendar. The Ethiopian calendar defines a month as consisting of 30 days. However, the difference in the total number of days per year – five days in common years and six days in leap years – is adjusted by an 'intercalary month,' which consists of those differences, in addition to the twelve standard months. Due to this adjustment, most Orthodox occasions take place during the same month of the Gregorian calendar across a year. For example, New Year's Day (January 1) in the Ethiopian calendar corresponds to September 11 in the Gregorian calendar (September 12 in a leap year). The last day of December in the Ethiopian calendar (December 30) is September 5 of the following year in the Gregorian calendar.

Table 3. Baseline results.

Outcomes	Death ≦1day (1)	Death ≦3m (2)	Death ≦1yr (3)	Birth-weight (4)	Birthweight < 2500 g (5)
Ramadan					
Exposed at T1	−0.003	−0.005	−0.002	43.19	−0.028
	(0.003)	(0.005)	(0.007)	(125.8)	(0.022)
Exposed at T2	−0.002	0.001	0.003	−167.4	−0.001
	(0.005)	(0.007)	(0.010)	(109.9)	(0.020)
Exposed at T3	−0.003	−0.002	0.004	9.620	−0.022
	(0.003)	(0.004)	(0.005)	(88.56)	(0.021)
Ramadan × Muslim					
Exposed at T1	0.005	0.021**	0.027**	18.05	−0.038
	(0.004)	(0.010)	(0.012)	(202.4)	(0.029)
Exposed at T2	0.000	−0.008	−0.005	144.3	−0.038
	(0.006)	(0.005)	(0.013)	(218.7)	(0.027)
Exposed at T3	0.008	−0.003	−0.005	−22.83	−0.034
	(0.005)	(0.006)	(0.013)	(213.4)	(0.024)
Ramadan × Protestant					
Exposed at T1	0.000	0.005	−0.012*	−129.6	0.022
	(0.008)	(0.009)	(0.007)	(216.2)	(0.100)
Exposed at T2	−0.005	−0.005	−0.012	−39.90	0.102
	(0.005)	(0.011)	(0.011)	(213.4)	(0.099)
Exposed at T3	0.002	0.010	−0.001	−292.7	0.332***
	(0.006)	(0.009)	(0.011)	(202.6)	(0.101)
Muslim	−0.001	0.003	0.002	99.22	0.044
	(0.003)	(0.007)	(0.011)	(223.6)	(0.037)
Protestant	0.000	−0.009	−0.008	144.7	−0.062
	(0.006)	(0.009)	(0.009)	(187.0)	(0.042)
Female	−0.001	−0.013***	−0.014***	−151.9***	0.018*
	(0.001)	(0.003)	(0.004)	(47.82)	(0.009)
Mom with primary edu.	0.002	0.004	0.003	−175.3*	0.038*
	(0.002)	(0.004)	(0.006)	(94.07)	(0.023)
Mom with secondary edu.	0.001	−0.001	−0.007	−128.9**	0.019
	(0.006)	(0.013)	(0.014)	(54.91)	(0.016)
Dad with primary edu.	0.001	0.001	−0.007*	9.799	−0.010
	(0.002)	(0.003)	(0.004)	(99.98)	(0.018)
Dad with secondary edu.	−0.001	−0.005	−0.011	101.8	−0.058
	(0.004)	(0.008)	(0.007)	(129.8)	(0.037)
Rural	0.001	0.006	−0.011	−99.87	0.065**
	(0.003)	(0.008)	(0.008)	(126.2)	(0.028)
Mean dep. var.	0.013	0.049	0.072	3,301	0.101
No. obs.	20,185	20,972	21,091	1,623	1,582
(Pseudo)*R*-sq	0.058	0.029	0.026	0.153	0.138

Notes: Columns (1)-(3) and (5) are based on Probit regressions and report marginal effects evaluated at zero for dummy explanatory variables and at the sample mean for continuous explanatory variables, while column (4) is estimated by OLS estimation. Additional controls include household characteristics (wealth level, whether the household lives in a rural area), information on parents (age at child birth, education level, and occupation of both mother and father, and mother's ethnicity, BMI, and current employment status), and child's information (birth order and gender). Birth month, year, and location fixed effects are also controlled. Standard errors, reported in parentheses, are clustered at regional level.
*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

we expect not to find any systematic difference in outcomes among Protestant Christian children depending on whether and when they were exposed to Ramadan *in utero*. That is, the estimates of $\gamma_{1,r}$, $\gamma_{2,r}$, and $\gamma_{3,r}$ with r being Protestant should be zero.

Table 3 reports the results. All reported estimates except for those in column (4) are marginal effects evaluated at zero for dummy explanatory variables and at the sample mean for continuous explanatory variables. Each column of Table 3 examines the corresponding five outcome variables – mortality measured at first day of birth, three months, and one

Table 4. Robustness checks.

Outcomes/Model	Log (no birth)	Size at birth: Below average	Female	Logit	OLS	Religion by Month FE	Probit
Sample	Cell	Baseline	Baseline	Baseline	Baseline	Baseline	7 regions
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Ramadan							
Exposed at T1	0.018	−0.019	0.004	−0.002	0.000	0.000	−0.006
	(0.036)	(0.019)	(0.014)	(0.007)	(0.008)	(0.008)	(0.009)
Exposed at T2	0.017	−0.003	0.024*	0.003	0.004	0.004	−0.009
	(0.029)	(0.014)	(0.014)	(0.010)	(0.011)	(0.011)	(0.012)
Exposed at T3	0.012	−0.010	0.015*	0.004	0.004	0.003	−0.002
	(0.013)	(0.008)	(0.008)	(0.005)	(0.006)	(0.006)	(0.007)
Ramadan × Muslim							
Exposed at T1	−0.003	0.038*	−0.014	0.023**	0.027**	0.031**	0.021**
	(0.044)	(0.020)	(0.017)	(0.011)	(0.012)	(0.014)	(0.010)
Exposed at T2	0.051	−0.004	−0.042*	−0.005	−0.005	−0.005	0.004
	(0.043)	(0.020)	(0.022)	(0.013)	(0.014)	(0.013)	(0.013)
Exposed at T3	0.083**	0.021	−0.042**	−0.005	−0.005	−0.004	0.014
	(0.037)	(0.024)	(0.017)	(0.013)	(0.014)	(0.012)	(0.011)
Mean dep. var.	0.569	0.321	0.487	0.072	0.071	0.072	0.073
No. obs.	9,559	21,143	21,259	21,091	21,271	21,091	14,273
(Pseudo)*R*-sq	0.158	0.049	0.005	0.026	0.014	0.030	0.033

Notes: Columns (1) and (5) are estimated by OLS estimation, columns (2),(3) and (6),(7) are based on Probit regressions, and column (4) is based on Logit regression. Marginal effects are reported evaluated at zero for dummy explanatory variables and at the sample mean for continuous explanatory variables for Probit and Logit estimation. In column (1), the unit of observation is a cell, defined by child's birth month, year, mother's religion, region, and household wealth status. We include birth month, year, and location, wealth category fixed effect, and controlled for the share of female children, share of households living in rural areas, both mother and father's average age at childbirth, and the share of primary and secondary education in each cell. In columns (2) – (6), the observation units are individual, using the whole sample. In Column (7), we exclude four regions (Affar, Gambella, Somali, and Tigray) where either Muslims or Orthodox Christians account for less than 10% of the residents. Except column (1), additional controls include household characteristics (wealth level, whether the household lives in a rural area), information on parents (age at child birth, education level, occupation of both mother and father, and mother's ethnicity, BMI, and current employment status), and child's information (birth order and gender). Birth month, year, and location fixed effects are also controlled except for column (6). In Column (6) religion by month fixed effects is used rather than month-fixed effects. Standard errors, reported in parentheses, are clustered at the regional level. Standard errors, reported in parentheses, are clustered at the regional level.

*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

year, birth weight, and whether a child was born underweight, respectively. Out of the 30 coefficients for Ethiopian Orthodox as well as the interaction effects for Protestants, all except for two estimates are not statistically significant at conventional levels. There are two noteworthy exceptions. One exception is $\gamma_{1,r}$ for whether a child was dead within one year (column (3), Table 3). However, the estimate is only marginally significant (at the 10% level), and is not robust across different specifications.[14] The other exception is $\gamma_{3,r}$ for whether a child was born underweight (column (5), Table 3). As explained earlier, we are concerned about selection bias in reporting birth weight, as only 8% of newborns report their weights. We will discuss this estimate further when we explain the main findings in Section IV.

[14] For example, the significance disappears if we restrict the sample to 7 regions where both the Muslim and Orthodox Christian populations are sizeable. We will explain this model when we discuss the robustness check in Section V.

The second type of analysis examines the extent to which Muslims respond to Ramadan in terms of the timing of births. Our identification strategy will fail if Muslim parents who care about their children's health time conception to minimize the possible negative effect of Ramadan. If our hypothesis is correct, then the number of births to Muslim parents will be smaller during Ramadan. To examine this possibility, we define a cell based on child's birth month and year, mother's religion (4 categories), region (11 categories) and household wealth status (5 categories), which generates a total of 9,595 cells. We then count the number of births for each cell and regress the natural logarithm of the number of births on control variables. The set of explanatory variables are in line with the control variables in equation (1). That is, we use the set of dummy variables whether the child was exposed to Ramadan *in utero* during a given trimester, religion fixed effect, and interactions of religion and the exposed trimester. Furthermore, we include birth month, year, and location, wealth category fixed effect, and control for the share of female children, share of households living in rural areas, and both mother and father's average age at childbirth, and the share of primary and secondary education.

If Muslim parents time conception to avoid Ramadan, then the estimated coefficient of Ramadan exposure for Muslims will be negative. By the same token, Orthodox Christians have no reason to adjust the time of conception in response to Ramadan, suggesting that the coefficients for Ramadan should be insignificant. The results reported in column (1) of Table 4 in general validate those hypotheses. We find no statistically significant patterns regarding the number of births and Ramadan exposure for Orthodox Christians. The Muslim-specific effect of the exposure in the first trimester (i.e. coefficient of 'Ramadan × Muslim: Exposed at T1') is estimated to be insignificant at conventional levels, and so is the effect of exposure in the second trimester. Although the effect of being exposed to Ramadan in the third trimester is significant at the 5% level, we are not concerned about this finding because our main findings rely on the newborns exposed to Ramadan in their first trimester, not those exposed in the third trimester.

4. Results

4.1. Outcomes at Birth

Mortality

Columns (1) to (3) in Table 3 report the estimates on infant mortality. Again, all reported estimates except for those in column (4) are marginal effects evaluated at zero for dummy explanatory variables and at the sample mean for continuous explanatory variables. Estimates of the interaction terms between Ramadan and Muslims (Ramadan × Muslims) suggest that Ramadan exposure in the first trimester has significant negative effects on Muslim children's chance of survival within three months and one year. Among the children who were exposed to Ramadan in the first trimester in utero, Muslim children have a 2.1%p (or 43%) and 2.7%p (or 38%) higher probability of dying within three months and one year respectively compared to children from Ethiopian Orthodox families. These negative effects of Ramadan are statistically significant at the 5% level. Our findings of the negative impacts of Ramadan can be directly shown in the summary statistics as well. In Table 2, we report the mortality rates among children exposed to Ramadan during the first trimester depending on their religious background. Although the average mortality

rate among Muslim children is lower than or comparable to that of Orthodox children, the mortality rate among Muslim children exposed to Ramadan in the first trimester is higher than that of Orthodox children. For example, the likelihood of being dead less than 3 months after birth is on average 4.7% among Muslim and 5.1% among Orthodox children. However, if we narrow the sample to only those exposed to Ramadan during the first trimester, the rate rises to 6.1% among Muslim children but not among Orthodox children (4.7%). Abundant medical literature reports that the first trimester is a critical period of fetal growth (e.g. Barker, 1995; Ramakrishnan et al., 2012). Thus, our finding that Ramadan exposure is particularly harmful to the fetus at an early stage of pregnancy is consistent with the literature.

To gauge the economic implications of our results, we conduct a back-of-the envelope calculation measuring the infant mortality if no Muslim children were exposed to Ramadan in the first trimester *in utero*. In our sample, 2,402 Muslim children were exposed to Ramadan in the first trimester *in utero*. As their mortality rate within a year is reduced by 2.7%p, the number of deaths would have decreased by 65. As we have 21,425 newborns in our sample, the reduction in the number of deaths corresponds to 3 fewer deaths per 1,000 live births.

Despite the government's efforts, Ethiopia still belongs to the group of countries with high infant mortality rates. In 2018, the number of deaths among 1000 live births was 39 in Ethiopia (World Bank Group, 2020), which ranks 36th out of 194 countries in terms of highest mortality rate. Our findings suggest that educating parents about the health risks of Ramadan and birth planning to avoid Ramadan in the first trimester can be a policy instrument to further reduce infant mortality in Ethiopia.

Birth Weight

Columns (4) and (5) in Table 3 present the effect of Ramadan exposure on birth weight and likelihood of being underweight. We do not find any statistically significant effects of Ramadan, partly because only a small number of children, 8% of our sample, report their birth weights.

Alternatively, we examine reported birth size as a proxy to measure birth weight and general health at birth. Column (2) in Table 4 reports the results. Like the previous results, Ramadan exposure in the second or third trimester has no significant effect on the likelihood of being underweight.

However, exposure in the first trimester increases the Muslim children's chance of being small size at birth by 3.8%p, statistically significant at the 10% level, relative to those who are Ethiopian Orthodox Christian and were exposed to the Ramadan in the first trimester. This finding is in line with our earlier finding from the mortality outcomes, suggesting that Ramadan exposure may be particularly detrimental to children in the early stage of pregnancy in terms of mortality. It is also consistent with the finding from Almond and Mazumder (2011), which identifies a negative impact of Ramadan exposure *in utero* on a child's birth weight.

Gender

Theories of biological selection suggest that males are more fragile than females *in utero* (Trivers & Willard, 1973), which suggests an increase in the fraction of newborn girls as a consequence of the mother's malnutrition due to Ramadan exposure. In the case of

Arab children in Michigan, Almond and Mazumder (2011) report that Ramadan exposure increases the possibility of female birth for those who are exposed to Ramadan only in the first month *in utero*.

To examine this possibility, we use the Probit model shown in equation (1) but replace the outcome variable as dummy for being female and omitting the female dummy from explanatory variables. Marginal effects are reported in Column (3) of Table 4. In our setting, we do not find evidence suggesting an increase in female births relative to males. Rather, we find the opposite effect.[15]

4.2. Later Life Outcomes

The Ethiopian DHS provides information on children's education and health status as long as they live with their parents. Using this information, we examine the extent to which Ramadan exposure may account for children's outcomes after birth.

Unfortunately, this examination is subject to an important data limitation. The limitation pertains to the fact that the DHS's children dataset includes neither the birth month nor an identifier to link the information from the mothers' data to that of the children. For our analysis, we combine the two datasets – the mothers' to infer birth month to predict Ramadan exposure and the children's to examine the current status. To match these two datasets, we link a child reported in the mother's data to one in the children's data if the two belong to the same household, have the same sex, and same birth year. This matching process finds 43% of the children reported in the mother's data.

We examine five outcome variables. Three health-related variables – height, whether a child is underweight, and whether a child shows anemia – are available for children whose age is 5 years or younger, the same as in our baseline sample. We classify a child as being underweight if his/her BMI is lower than the value of the 5th percentile among children of the same age and gender. The World Health Organization (WHO) provides a set of references for children's growth. Among them, we use the BMI distribution for reference, to examine children of a given age and gender.[16] For anemia status, DHS provides an anemia diagnosis result using a child's hemoglobin level. The remaining two variables are related to educational attainment: whether a child whose age is between 7 and 11 is currently enrolled in a primary school, and whether a child whose age is between 15 and 20 graduated from a primary school.[17] We focus on primary schooling because most Ethiopians have no primary school degree.

Estimation results are reported in columns (1) to (5) in Table 5. In all columns except for (1), we use the Probit regression model presented in equation (1), while we estimate linear regression models for height. For Probit models, we report marginal effects evaluated at zero for dummy explanatory variables and at the sample mean for continuous explanatory variables. For most cases, we do not find significant evidence suggesting prolonged effects of Ramadan exposure *in utero*. Almost all point estimates of 'Ramadan × Muslims: exposed at T1, T2, and T3' are statistically insignificant at conventional levels. One exception is the

[15] We do not emphasize our finding of the opposite effect among the children exposed in the second or third trimester. This is because exposure to Ramadan is significantly correlated with a child's gender among non-Muslims, causing concerns about identification strategy for this outcome variable.

[16] See details at https://www.who.int/childgrowth/standards/bmi_for_age/en/

[17] According to the Ethiopian Ministry of Education (2013), primary schooling requires 4 years, starting from age 7.

Table 5. Later-life outcomes.

Outcomes	Current Height	Current Underweight	Current Anemia	Currently enrolled in a school	Graduated Primary school
Sample	Baseline	Baseline	Baseline	Aged 7–11	Aged 15–20
	(1)	(2)	(3)	(4)	(5)
Ramadan					
Exposed at T1	0.842**	0.021	−0.004	−0.016	−0.011
	(0.319)	(0.023)	(0.034)	(0.028)	(0.022)
Exposed at T2	0.581	0.001	−0.023	−0.022	−0.023
	(0.326)	(0.013)	(0.036)	(0.035)	(0.029)
Exposed at T3	0.771***	0.010	−0.065	−0.002	−0.025
	(0.142)	(0.010)	(0.041)	(0.014)	(0.021)
Ramadan × Muslim					
Exposed at T1	−0.507	−0.014	−0.050	0.024	0.048
	(0.478)	(0.022)	(0.043)	(0.037)	(0.030)
Exposed at T2	−0.050	0.003	−0.021	0.072	0.055
	(0.312)	(0.022)	(0.026)	(0.045)	(0.038)
Exposed at T3	−0.818**	−0.015	−0.008	0.040	0.047
	(0.302)	(0.015)	(0.038)	(0.032)	(0.048)
Mean dep. var.	81.66	0.154	0.536	0.477	0.268
No. obs.	10,255	10,169	5,142	8,414	3,204
(Pseudo)*R*-sq	0.754	0.077	0.116	0.283	0.488

Notes: Column (1) is estimated by OLS estimation, and columns (2) – (5) are based on Probit regressions using the corresponding sample, reporting marginal effects evaluated at zero for dummy explanatory variables and at the sample mean for continuous explanatory variables. Additional controls include household characteristics (wealth level, whether the household lives in a rural area), information on parents (age at child birth, education level, occupation of both mother and father, and mother's ethnicity, BMI, and current employment status), and child's information (birth order and gender). Birth month, year, and location fixed effects are also controlled. Standard errors, reported in parentheses, are clustered at the regional level.
*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

coefficient of 'Ramadan × Muslims: exposed at T3' for height (column (4)). However, the estimated coefficients for Orthodox (i.e. 'Ramadan: exposed at T1, T2, and T3') are also statistically different from zero, undermining our identification strategy. Different from Van Ewijk (2011) and Karimi and Basu (2018), we do not find sufficient evidence suggesting that Ramadan exposure induces prolonged negative impacts on children.[18]

5. Robustness Check

We examine the robustness of our main findings by employing alternative specifications. In this subsection, we focus only on mortality rates measured one year after birth because this outcome shows strong effects of Ramadan.

In columns (4) and (5) in Table 4, we report the estimated marginal effects from a Logit and an OLS model instead of a Probit model respectively. Exposure to Ramadan during the first trimester significantly increases a Muslim child's likelihood of being dead within one year after birth (2.3%p and 2.7%p for Logit and OLS respectively), very similar to the result from the baseline (2.7%p).

[18] Van Ewijk (2011) reports a prolonged negative effect of Ramadan on adult health using the Indonesia Family Life Survey, while Karimi and Basu (2018) document the negative effect of Ramadan on height using Demographic and Health Surveys (DHS) data from 37 developing countries.

Next, we use religion by month fixed effects, instead of month-fixed effects, to further tease out the possible time-varying difference between Muslim and non-Muslim infants. Column (6) reports the results. The point estimates for the Muslim children exposed to Ramadan during the first trimester, relative to those who are Ethiopian Orthodox, are almost identical to the baseline results (i.e. 3.1%p vs 2.7%p for one-year mortality).

In column (7), we re-estimate our baseline model with a sample restricted to 7 regions that have sizable Muslim and Orthodox Christian populations. Our identification relies on within-region comparison between Orthodox Christian and Muslim children who have different degrees of exposure to Ramadan *in utero*, so a comparable share of each religion is required. Because we include region-fixed effects in our baseline model, the regions that predominantly contain one religious group will not directly affect our estimation results. Nonetheless, we examine the robustness of our results by using a subsample of regions that have both Muslim and Ethiopian Orthodox as major religions. To do so, we exclude four regions (Affar, Gambella, Somali, and Tigray) because either Muslims or Orthodox Christians account for less than 10% of their residents, and re-estimate the baseline model with only the remaining 7 regions. The results are qualitatively the same as those in the baseline. We do not find any statically significant effects of Ramadan on Orthodox children, while Muslim children exposed to Ramadan in the first trimester are 3.1%p more likely to die within one year after birth than their peers who were not exposed to Ramadan.

6. Conclusion

This paper examines the impact of Ramadan exposure *in utero* on birth outcomes as well as later life outcomes in the context of Ethiopia. Our empirical results imply that exposure to Ramadan *in utero* in the first trimester substantially increases a Muslim child's likelihood of being dead within three months and one year after birth, relative to their counterparts from Ethiopian Orthodox families. However, different from a few existing studies, we do not find robust results suggesting that Ramadan exposure affects sex composition among newborns, birth weight, or other later life outcomes. The results imply that the prevailing concept that Ramadan exposure is harmful varies by country and outcomes, and it is also confirmed by analyzing Ethiopia's case.

Our findings have important policy implications. The Ethiopian government has been devoting a substantial amount of effort to reducing infant mortality. According to Ruducha et al. (2017), 143 million US 2012 dollars was spent on average each year between 2005 and 2011 on child health, which is 12% of the total health expenditure in Ethiopia. In addition, in 2003, the government launched the *Health Extension Programme* to achieve universal coverage of primary health care in an attempt to meet the Millennium Development Goals, which include reduction in infant mortality. Although it has decreased drastically (78 per 1000 live births in 2003 vs. 39 in 2018), Ethiopia's infant mortality rate is still high, ranking 36th among 194 countries (World Bank Group, 2020). Considering the significant negative effects of Ramadan and the prevalence of Muslims in Ethiopia's population, it will be worth devising a policy to mitigate the negative effects. Possible policy instruments include information campaigns for Muslim parents to time conception to avoid first trimester exposure to Ramadan.

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