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Prenatal Nutrition and Adult Outcomes: The Effect of Maternal Fasting During Ramadan*

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Abstract

We use the Islamic holy month of Ramadan as a natural experiment for evaluating the long-term effects of fasting during pregnancy. Preliminary results using Michigan natality data show that babies of Arab descent who were *in utero* during Ramadan have lower birthweight compared to those who were not *in utero* during Ramadan. Using Census data in Uganda we also find that Muslim adults who were born nine months after Ramadan are 22 percent (p =0.02) more likely to be disabled. Effects are found for vision, hearing, and mental disabilities and may reflect neurological impairments from disruptions to early fetal development. We find no evidence that negative selection in conceptions during Ramadan accounts for our results. We urge caution in interpreting these results since we cannot directly link the incidence of adult disability with adverse fetal conditions.

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1 Introduction

There is now a growing recognition among researchers that environmental conditions during fetal development have potentially important long-term effects on health and socioeconomic outcomes. The"fetal origins" hypothesis associated with the work of David Barker, maintains that adverse conditions in the intrauterine environment lead to adaptive changes, that while beneficial in the short-run for fetal development, could lead to permanent alterations in the body's systems. These changes may be manifested in poor health outcomes such as diabetes and heart disease later in life. Given that hunger and lack of nutrition affects a sizable fraction of the world's population, understanding the potential long-term effects of insufficient prenatal nutrition is clearly an issue of enormous concern. While there is a vast literature on this topic, efforts to identify causal effects are plagued by concerns about confounding factors. Individuals receiving inadequate nutrition during fetal development are also likely to face disadvantages in virtually all other dimensions of early life (e.g. poor living conditions, inadequate education, lack of access to health care).

This study uses a new research strategy that potentially offers a compelling way to identify the effects of maternal nutrition on children's long-term outcomes. We use the observance of fasting during the Islamic holy month of Ramadan as a natural experiment to isolate such effects. Specifically, we compare the outcomes of Muslims who were exposed to Ramadan *in utero* to those who were not. We utilize a wide birth interval so as to utilize the movement of Ramadan across different calendar months (in the Western calendar), depending on the calendar year of birth. We can therefore disentangle Ramadan effects from those attributable to the season of birth. To our knowledge, no previous study has utilized this research design. Our approach contrasts with many of the medical studies of Ramadan that have typically only compared fasting pregnant mothers to non-fasting pregnant mothers at a point in time and have only examined short-term outcomes such as birthweight. Since these studies cannot, for obvious ethical reasons, randomly assign pregnant women into treatment and control groups they are unable to control for unobservable factors that might differ between the groups.[1] Our approach does not rely on the assumption that there are no differences between fasters and nonfasters during Ramadan but rather that there are no systematic differences among Muslims in the timing of Ramadan relative to their fetal development. While our identification is based on cross-cohort differences only among Muslims, we also check the validity of our results by comparing them to estimates produced on samples of non-Muslims, who presumably would not observe the Ramadan fast and for whom therefore, we should fail to see comparable effects.

While Ramadan constitutes an appealing research design, understanding the long-term health effects of Ramadan is clearly important in its own right. Approximately a fifth of the world's population is Muslim suggesting several hundred million women will fast each year during Ramadan. Many of these women will be pregnant and some will not yet be aware that they are pregnant.

During the lunar month of Ramadan, healthy Muslim adults are required to fast. Fasting includes abstaining from eating and drinking any beverages, as well as sex, during daylight hours. Certain persons are automatically exempted from fasting: "children, those who are ill or too elderly, those who are travelling, and women who are menstruating, have just given birth, or are breast feeding":Esposito (2003). As we will show, although pregnant women may request a special dispensation from fasting by making up the days later, evidence from a variety of surveys across many countries suggests that the vast majority (e.g. 75 percent or more) prefer to observe the fast with their families. In addition, since many women will not know they are pregnant during the first month or two of gestation, they may observe the fast in the absence of such knowledge.

The fact that Ramadan is based on the lunar calendar implies that the start date shifts forward 11 days every year Julian year. As a result of this forward seasonal drift and its month-long duration, more than three quarters of pregnancies overlap with Ramadan. The forward drift also implies that over a thirty two year period Ramadan will have taken place

[1] This criticism clearly does not apply to the biomedical studies that trace an individual's biochemical profile through the course of a day of fasting.

over the entire calendar year. Therefore by observing sixty birth cohorts (as we do in our Ugandan sample), we can be reasonably confident that we can separate seasonal effects from Ramadan effects.

It is well established that even short fasts can have immediate impacts on pregnant mothers, a phenomenon referred to as "accelerated starvation" (Metzger et al. (1982)). Essentially, the body begins to break down stores of fat in response to nutrient deprivation as it does in the case of actual starvation. For pregnant women, skipping one meal can initiate these changes; such rapid onset is not observed among women who are not pregnant. These biochemical changes have been found specifically in the case of Ramadan fasting among pregnant women (e.g. Prentice et al. (1983)). One particular concern is whether "ketones", which are released during the process may impair the neurological development of the fetus as has been found in some animal studies. In addition, studies of pregnant mothers fasting during Ramadan have shown evidence of reduced fetal breathing movements, higher incidence of gestational diabetes and increased rates of admission to special baby care units. On the other hand, there is only mixed evidence on whether fasting during Ramadan affects birth indicators such as birthweight. We note, however, in our literature review that many of the studies on birthweight suffer from questionable research designs and small samples. In any case, some studies have shown divergent biochemical changes among Ramadan fasters even though birthweight was unaffected. Therefore, it is unclear whether birthweight serves as a useful indicator of potential impairments to fetal development that arise from fasting.

The fetal origins literature also suggests a variety of mechanisms by which impairments to the intra-uterine environment could result in long-term health effects. For example, there is considerable evidence from animal studies that nutrient restriction can lead to a "reprogramming" of the hormonal system (Kapoor et al. (2006)). This has been shown to lead to altered functions that are sometimes only manifested later in life and that may result in adverse health outcomes. The effects appear to vary by species, the timing of fetal exposure, and are sex-specific. However, we are unaware of any previous studies that have examined adult outcomes among those who were subject to in-utero exposure to intermittent fasting during Ramadan.

Our main analysis utilizes the 2002 Uganda Census because it is an easily accessible dataset that provides information on month of birth and religion for a large sample of both Muslims and non-Muslim adults. This Census also includes a relatively detailed set of health questions. Since we cannot use these data to link the effects of fasting to fetal development directly, we supplement the analysis with natality data from the state of Michigan –which has a very large Arab population, the vast majority of whom are Muslim. With this data we can observe immediate birth outcomes that potentially could be affected by fasting, such as birthweight.[2] In future drafts, we plan to report our analysis from the 2000 Indonesian Census. Due to the lack of health measures, we will primarily use the Indonesian data to explore the effects of fasting on the sex ratio. In addition, we will also analyze various socioeconomic outcomes, such as years of schooling and marital status.

Using our Uganda sample, we find that the occurence of Ramadan nine months prior to birth is associated with an increased likelihood of having a disability in adulthood by about 20 percent. Specifically, sight, hearing and mental (or learning) disabilities are significantly elevated. No such effects are found among non-Muslims adults or among Muslims exposed to Ramadan later in pregnancy. Since aural and ocular function depends on neurological development during the third and fourth weeks after conception, these disabilities are consistent with an impaired environment during the first month of fetal development.

We also find that among the causes of disability, the early gestation effects are associated with accelerated "aging", also consistent with the fetal origins hypothesis. Importantly, these effects are not due to factors such as accidents, injury or war (which would suggest subsequent "period" rather than the hypothesized cohort effects).

Due to the lack of large-sample data on birth outcomes, we are unable to analyze fasting and fetal conditions in Uganda. In lieu of such data, we turn to natality data from Michigan,

[2] Used extensively as a proxy for future health problems in the fetal origins literature.

home to a large Muslim population. Here, we find that birthweight is lower among infants of Arab descent who were exposed to Ramadan *in utero*. Those in the first month of gestation during Ramadan were 40 grams lighter at birth. When Ramadan falls during the summer when daylight hours are considerably longer (and therefore the fast), the estimated effect is larger – around 60 grams. Although these effects are small relative to the mean birthweight of about 3300 grams they are a significant fraction of the estimated birthweight effects of smoking (200 grams) and the black-white birthweight gap (100 grams).

We also find large effects on the adult sex ratio in Uganda that are consistent with the Trivers-Willard (1973) hypothesis that men are adversely affected if their mothers face poor environmental conditions. We also find suggestive evidence of this effect for Indonesia if there is fetal exposure to Ramadan during the first gestation month.[3]

Our identification strategy assumes mothers who are pregnant during Ramadan are comparable to women whose pregnancies do not overlap with Ramadan. If for example, healthier mothers systematically time conceptions to take place shortly after Ramadan to avoid fasting during pregnancy then this might invalidate our approach. We address this by examining whether observable measures such as mother's education varies systematically with exposure to Ramadan during pregnancy. We find no evidence of selection into conception by the timing of Ramadan.

Although these results are strongly suggestive of a link between daytime fasting and reduced birthweight and adult disability, we recommend caution in interpreting the findings. Our data cannot for example, show whether or not the individuals experiencing disabilities actually experienced adverse fetal conditions. We only know that the timing of their birth is consistent with such an effect. In addition, while our analysis does not suggest that selection into conceptions accounts for our results, there may be unobservable attributes influencing birth timing that we have not accounted for.

[3] Omitted from this version of the paper.

2 Literature Review

2.1 Do Pregnant Muslim Women Fast During Ramadan?

Pregnant women may be exempted from Ramadan fasting. However, they are expected to "make up" the fasting missed during pregnancy after delivery, see, e.g., Malhotra et al. (1989). Anecdotal evidence suggests that this requirement prevents many pregnant women from opting not to fast. A public health professional recounting her experience in Yemen claimed that many women "did not want to have to make the time up later, when they would be the only member of the household fasting" (Hoskins (1992)). Mirghani et al. (2004) noted: "Most opt to fast with their families rather than doing this later":636. In addition, some Muslims interpret Islamic Law as requiring pregnant women fast. For example, the religious leader of Singapore's Muslims held that: "a pregnant woman who is in good health, capable of fasting and does not feel any worry about herself or to her foetus, is required and expected to fast like any ordinary woman": Joosoph and Yu (2004).[4]

Comprehensive data on Ramadan fasting during pregnancy do not exist. Various surveys of Muslim women suggest that fasting is the norm. For example, of the 4,343 women delivering in hospitals in Hamadan, Iran in 1999, 71% reported fasting at least 1 day, "highlighting the great desire of Muslim women to keep fasting in Ramadan, the holy month:"Arab and Nasrollahi (2001).[5] 87% of the 181 muslim women surveyed in Singapore fasted at least 1 day during pregnancy, and 74% reported completing at least 20 days of fasting: Joosoph and Yu (2004). In a study conducted in Sana'a city, Yemen, more than 90 percent fasted over 20 days. At the Sorrento Maternity Hospital in Birmingham, England, three quarters of mothers fasted during Ramadan (Eaton and Wharton (1982)). In a study conducted in Gambia, 90 percent of pregnant women fasted throughout Ramadan (Prentice et al. (1983)).

[4] Similarly, Arab and Nasrollahi (2001) noted that "According the Islamic teaching pregnant women are allowed to fast if it is not harmful to them"; faculty at the Kurdistan Medical Science University in Iran noted that pregnant and breastfeeding women "who fear for the their well being or that of the foetus/child" may be exempted from fasting: Shahgheibi, Ghadery, Pauladi, Hasani, and Shahsawari (2005).

[5] 54% reported fasting 10 days or more:Arab and Nasrollahi (2001).

In the US, a study of 32 Muslim women in Michigan found that 28 had fasted in at least one pregnancy and reported that 60-90 percent of women from their communities fast during pregnancy(Robinson and Raisler 2005).

We have only found one study that carefully examines changes in women's weight over the course of Ramadan using panel data. Using a sample of women in Gambia and using individual fixed effects and controlling for calendar month and year effects, (Ulijaszek and Strickland 1993) found striking evidence of dramatic weight changes during Ramadan confirming the high degree of fasting during Ramadan. In any case, the fact that observance is not 100% only suggests that any population-wide effects that are found are likely to understate the true effects on the average individual.

2.2 Biochemical and Biophysical Changes: Accelerated Starvation

Metzger et al. (1982) writing in *Lancet* describe a phenomenon of altered chemical conditions called "accelerated starvation" in pregnant women who skipped breakfast in the second half of pregnancy. Relative to twenty-seven non-pregnant women with similar characteristics, "circulating fuels and glucoregulatory hormones" changed profoundly in twenty-one pregnant women when the "overnight fast" was extended to noon on the following day. Further, plasma glucose was lower in the pregnant women than non-pregnant women after over 12 hours of fasting. "Accelerated starvation" in pregnancy occurred after only "minor dietary deprivation". Metzger et al. (1982) concluded that meal-skipping "should be avoided during normal pregnancy":591. As similar metabolic changes were observed in both 'lean" and "obese" pregnant women, BMI did not appear to provide a protective effect. One specific concern is whether "ketones" produced as a result of these changes could potentially impair the intellectual development of the fetus. Experimental studies in mice and rats have shown that prenatal exposure to ketones result in impaired neurological development.(Hunter and Sadler (1987); Moore et al. (1989); Sheehan et al. (1985)). Moore et al. (1989) noted that "even a relatively brief episode of ketosis might perturb the development of the early embryo":248.

Prentice et al. (1983) specifically find that fasting during Ramadan led to accelerated starvation in a study that compared chemical changes in pregnant women to non-pregnant women who fasted in Gambia. Pregnant women who fasted had significantly lower levels of glucose and alanine and significantly higher levels of free fatty accids and beta-hydroxybutyrate, a ketone. These changes were also associated with poor pregnancy outcomes such as still birth and low birthweight. Mirghani et al. (2004) studied 63 pregnant women at weeks gestation 30 or more, comparing outcomes during a period of fasting and shortly after the fast was ended. Maternal glucose levels were lower during fasting, as was the "continuous variety of fetal breathing movement". The number of days fasted appeared to have an independent effect, suggesting "the effect on maternal glucose levels during Ramadan fasting is cumulative":636. [6] Malhotra et al. (1989) found that 11 pregnant women observing Ramadan fast all had divergent biochemical blood readings as the fast day concluded, including lower plasma glucose. Glucose, in turn, is "a major nutrient for fetal growth and energy": Cunningham et al. (2001):140.[7] Malhotra et al. (1989) conclude it is "prudent to recommend that mothers take up the dispensation offered to them during Ramadan, i.e. postpone their observation of the fast until after their pregnancy is completed":617.

In addition to accelerated starvation, other adverse health outcomes to the fetus have been identified. Mirghani et al. (2003) found reduced fetal "biophysical profiles" among 81 pregnant women fasting for Ramadan, when compared with 81 non-fasting controls. Mirghani and Hamud (2006) compared 168 pregnant fasters to a control group of 156 non-fasting mothers and found significantly higher rates of gestational diabetes, induced labor,

[6] The profiles include: fetal body and limb movements, fetal tone, fetal breathing movements, and amniotic fluid volume. Changes in fetal breathing movements drove the results: Mirghani et al. (2003).

[7] As an aside, we note that the twinning rate may also respond to maternal nutrition:Cunningham et al. (2001):770. In particular, we plan to evaluate whether Ramadan exposure early in gestation may reduce twinning.

and admission to the special baby care unit.

2.3 Birthweight and Other Indicators

The literature has found mixed evidence with respect to birth indicators such as birthweight, although most studies have shown no significant effect. The sample sizes in most studies tend to be quite low and several studies appear to use questionable control groups. Kavehmanesh and Abolghasemi (2004) compared 284 births to mothers in Tehran with a "history of fasting during pregnancy" to 255 mothers who did not fast. No statistically significant differences in weight, height, and, and maturity between the two groups were found. It is worth noting, however that pre-pregnancy BMI's were substantially higher in the fasting group raising concerns about the design of the study. Shahgheibi et al. (2005) studied only 179 newborns for whom Ramadan fell in the third trimester of pregnancy. Among fasters, birth weight was lower by 33 grams, birth length was lower by about 0.2 centimeters while head circumference was larger by 0.08 centimeters. Since these differences were not statisitically significant with the small sample used, the authors concluded that fasting during the third trimester had "no effect" on growth indices. Arab and Nasrollahi (2001) studied 4,343 pregnancies in the Hamdan province of Iran. 71% of mothers fasted during pregnancy. Interestingly, fasting was more common when Ramadan fell in the first trimester (77%) than in the third trimester (65%): table 1. Regardless of trimester, the authors concluded that fasting did not impact birth weight. They did note however, that the incidence of *low birth weight* was higher among fasters in the second trimester but that this was significant only at the 9 percent level.

The largest and perhaps most commonly cited study on the effects of Ramadan on birth weight conducted a retrospective analysis of 13,351 babies born at full term from 1964-84 in Birmingham, England (Cross, Eminson, and Wharton 1990). Babies were categorized as Muslim on the basis of the first three letters of the mother's surname and were matched to control groups by age. However, this study did not compare the birthweights of Muslims in utero during Ramadan to Muslims who were not in utero during Ramadan. In addition, by design the study did not look at the potential effects of Ramadan on gestation length. Although they find no significant effects on mean birth weight, as was the case with Arab and Nasrollahi (2001), Cross et al. (1990) also find a higher incidence of low birth weight among fasters during the second trimester. Finally, Opaneye, Villegas, and Azeim (1990) find that in Al-Kharj, Saudi Arabia, the incidence of low birth weight increased during Islamic festivals, Ramadan in particular. 9.9% of the 415 births were below 2,500 grams during Ramadan, versus 6.3% for the 4,865 births in non-Ramadan months.

While many of the studies discussed find no effect on birthweight, it is worth noting that both Malhotra et al. (1989) and Mirghani and Hamud (2006) also found no effects on birth indicators such as birthweight and apgar scores despite finding dramatic evidence of biochemical changes. Therefore, this suggests that one should not assume that simply because birthweight is unaffected that this necessarily implies no harmful effects to fasting.

2.4 Maternal Fasting and "Fetal Programming"

Kapoor et al (2006) summarize the literature on how parental stress, including restricted maternal nutrition during pregnancy, could have long-term impacts on the child. Specifically, they describe how impairments to the fetal environment could alter the hypothalamo-pituitary-adrenal (HPA) function causing modifications that may be manifested in poor health outcomes later in life. They suggest that this reprogramming may make sense as s survival mechanism:

> "As humans, perhaps we have inherited a sophisticated mechanism to adapt our offspring to the environment into which they are to be born. However, if this process is set in motion by a compromised or modified pregnancy (e.g. placental insufficiency, stress, nutrient restriction or glucocorticoid treatment), whether or not this is related to the environment into which the fetus will be born, the outcome will be modification of endocrine, behavioural, cardiovascular

and metabolic regulation."

Based largely on animal studies, the effects of fetal programming of HPA appears to vary based on the specific species that is being studied, the timing of exposure during fetal development and the sex of the animal. IThe effects of fetal programming of HPA in humans may result in cognitive impairment and that due to the complex feedback mechanisms involved, these effects may not be evident "until adulthood or early old age".

To date, we have not found any previous studies that trace adult health (or socioeconomic) outcomes back to prenatal Ramadan exposure. The study closest to ours is by Azizi et al. (2004), who surveyed 191 children (and their mothers) enrolled in 15 Islamic primary schools in Iran. Approximately half of the mothers selected for the analysis sample reported fasting during pregnancy.[8] Among fasting mothers, those fasting during the third trimester were over-sampled. No significant difference in the IQ's of the children were found by maternal fasting behaviour.

3 Data and Methodology

3.1 Michigan Natality Files

From the state of Michigan we obtained data on all births over the 1989 to 2005 period. Michigan is especially useful for this analysis because of its large Arab population, the vast majority of whom are Muslim. According to the Arab American Institute, there are close to 500,000 Arabs living in Michigan, making it the second largest state behind California in terms of its Arab American population. About two-thirds of those who identify themselves as Arab in the Census describe themselves as of Arab or Chaldean (Iraqi) ancestry. We are not aware of any direct estimates of the number of Muslims in Michigan.

[8] More than 1,600 mothers returned questionnaires regarding their fasting behaviour during pregnancy. However, the fraction of this initial sample who fasted during pregnancy is not reported by Azizi et al. (2004).

The natality data identifies the ancestry of the mother by country allowing us to classify "arab" status. We then use this as a proxy for whether the mother is muslim. Data is collected a number of health related birth outcomes including birthweight, 1 minute and 5 minute Apgar scores and a variety of specific adverse health outcomes such as diabetes. However, since we are primarily concerned about measuring *long-term* health consequences, we focus here primarily on birthweight effects in order to first establish the plausibility that fasting during Ramadan actually affects the fetus in the most obvious and easily measured way. Unfortunately, we do not have data that tracks these children further in life making it impossible to measure future outcomes. We also do not have information on biochemical or biophysical conditions during fetal development that some of the Medical studies have examined.

In total we have a sample of about 40,000 births to mothers of Arab ancestry. We exclude cases where the fathers are not of arab ancestry and we exclude twins from the analysis. While Arab births among fetuses that faced no exposure to Ramadan serve as a primary control group, we also estimate our models on births to mothers of non-Arab ancestry as an additional validity check.[9] In total our non-Arab sample consists of over 1.5 million births.

3.2 Uganda Census 2002

The bulk of our analysis uses the 2002 Uganda Census maintained by the Minnesota Population Center as part of its Integrated Public Use Microdata Series — International (IPUMS-I) collection. Uganda is the only country in the IPUMS-I with a very large muslim population for which information on both month of birth and religion are collected.[10] The Uganda sample is a 10% sample of the population and the entire sample contains about 2.5 mil-

[9] We dropped births with no reported ancestry or where the ancestry might possibly include parents who are practicing Muslims (e.g. Southeastern Asians). We also dropped non-Arab to avoid the possibility that there might be "Black Muslims" in our sample.

[10] Birth month and religion are avalaible in the census of South Africa (unharmonized variables in IPUMS-I), but the share of Muslims is extremely small.

lion individuals. Our main sample includes men and women between the ages of 20 and 80. Individuals whose birth month or birth year were imputed have been dropped from the analysis.[11] For each outcome we also recoded those with imputed data as missing. We used information on the following outcomes: years of schooling, having ever attended school, literacy, employment status, working in an elementary occupation and disability. The disability question in the Uganda census asks "Does (name) have any difficulty in moving, seeing, hearing, speaking difficulty, mental or learning difficulty, which has lasted or is expected to last 6 months or more? The following specific disabilities are recorded in the dataset: blind or vision impaired, deaf or hearing impaired, mute, disability affecting lower extremities, disability affecting upper extremities, mental/learning disabilities and psychological disabilties.[12]

There is also a question that asks about the origin of the disability. The responses are coded into the following variables: congenital, disease, accident, aging, war injury, other or multiple causes. Finally there are variables dealing with how the disability has been rehabilitated (e.g. surgery, medication, assistive devices) which we have not utilized.

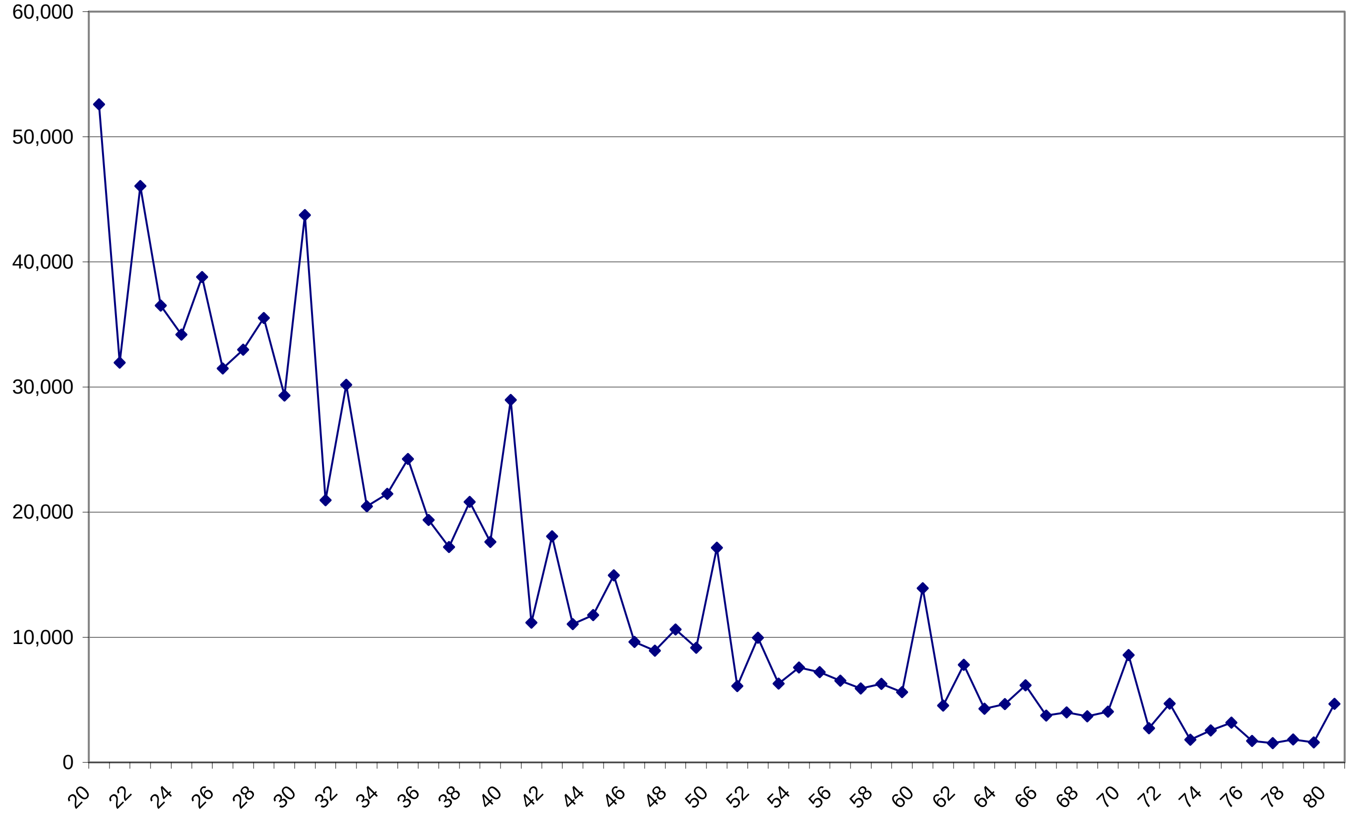
The summary sample statistics are described in Tables 1A for the full sample and are broken down by sex in Tables 1B and 1C. About 11 percent of our sample are Muslim. Muslims in Uganda have lower levels of illiteracy, more schooling and lower disability rates. We also find that although there are striking seasonal patterns in timing of birth that these patterns are common among muslims and non-muslims.

Since our analysis relies on correctly measuring the timing of one's birth, we want to ensure that we have eliminated obvious sources of measurement error. In Figure 1 we have

[11] To obtain imputation flags users must utilize the unharmonized variables provided by IPUMS-I. We allowed for "logical imputations" but dropped those who were imputed by a hot-deck procedure.

[12] The original unharmonized variables label the last two variables "mental retardation" and "mental illness" while the Minnesota Population Center relabelled them as "mental" and "psychological". Our own reading of the instructions to the Uganda Census enumerators suggests that this relabelling was appropriate. The former appears to identify those with "mental or learning disabilities" while the latter identifies those exhibiting "strange behaviors".

Figure 1: Uganda 2002 Census: Sample Size by Age



plotted the sample size by age. It is immediately evident that there are large spikes in reporting of ages that end in zeroes (e.g. 20, 30, 40). Clearly using the birth years of these individuals will lead to measurement error in the recording of Ramadan's occurence during gestation. Therefore, we exclude those individuals whose reported age ends in zero.

3.3 Indonesia Census 2000

Indonesia is home to the largest Muslim population in the world. Muslims make up between 85% and 90% (Esposito (2003)) of the more than 200 million Indonesians. The 2000 Census queried the month and year of birth of each respondent, as well as the province of birth. Importantly, religion is reported: Muslim, Catholic, Protestant, Hindu, Buddhist, or other. Like Uganda, this permits construction of a ready control group. Unfortunately, and unlike the Uganda Census, no questions regarding disabilities were asked. Reported Census outcomes include: gender, marital status, educational attainment, employment status, and for women, the number of children born and the number of live-born children surviving. Astoundingly, the Indonesian Census is not a sample but a near universe of Indonesians. In future versions of the paper we may utilize this data.

3.4 Ramadan Measures

In order to construct the measures of Ramadan exposure we first identified all the historical dates for Ramadan in the Christian calendar during the 20th century.[13] We then constructed measures of Ramadan exposure utilizing information either on birth month or birth date. When we only have access to birth month, we calculate the fraction of days in the month that overlap with Ramdan. We opted to use this measure, *rampct,* rather than a simple dummy variable since it provides a continuous measure of treatment. When exact birthdate is available as it is in the Michigan data, we constructed several measures of Ramadan exposure tied to each *day* during the twentieth century.[14] These include the percent of Ramadan days during the subsequent week, two weeks and month. In this analysis we have only used the percent of of days over the next month, *exppct.* In principle, if one knew the conception date or the length of gestation, this could be used to identify Ramadan effects tied to specific days within the pregnancy period.

For Michigan, we also assembled data on the number of daylight hours during each day from 1989 to 2005 in the city of Dearborn which is home to a large Arab population. We used this to construct a measure designed to distinguish periods of prolonged fasting from shorter periods. The numerator of this measure is the number of daylight hours over the next 30 days that are during Ramadan and the denominator is the maximum number

[13] There are many websites that translate dates from the Islamic (Hijri) calendar to the Gregorian calendar. We used the following website http://www.oriold.unizh.ch/static/hegira.html but verified the dates from a second source.

[14] Results with these data sources may be incorporated in future drafts.

of daylight hours over any 30 day period over the entire sample period. Daylight hours in Michigan vary from a low of around 9 to a high of 15. The evidence on accelerated starvation suggests that the effects might be much different depending on the total fasting time. Since Uganda is at the equator, the number of daylight hours is fairly constant over the year at 12. Similarly lies on both sides of the equator.

3.5 Econometric Model

Our main approach is to regress each outcome, y, on our measures of Ramadan exposure (*rampct* or *exppct*) during the 9 months preceding birth. Our controls include birth year dummies, a set of birth month dummies and a set of dummies that measure geographic location at the time of birth[15]. In the Michigan analysis we also include mother's years of education, mother's age and mother's age squared. In our pooled samples of adult men and women we include a female dummy.

$$y_{iyms} = \alpha + fem + year_y + month_m + state_s + rampct_t + \varepsilon_i, (t = 1, ...9) \tag{1}$$

The estimates are run separately for our Muslim and Non-Muslim samples so that birth timing and birth location effects are allowed to vary across groups. As we discuss later, we also run these models separately by sex. For some estimates (e.g. sex ratio in Uganda) we use aggregate measures at the cell level where cells are defined by each of the distinct birthmonths over the sample period.

We also run a second set of models where we substitute a measure of no *in utero* (*niu*) exposure during Ramadan for our *rampct* or *exppct* variables. The coefficient in this case reflects the effects on the outcome of zero exposure to Ramadan related fasting at any time during gestation. If there are negative effects of *in utero* exposure then we expect the coefficient on *niu* to be positive.

[15] In Michigan we have a set of 84 dummies for counties of residence and in Uganda we have a set of 56 district of birth dummies.

$$y_{iyms} = \alpha + fem + year_y + month_m + state_s + niu + \varepsilon_i, (t = 1, ...9) \quad (2)$$

3.6 Assumptions and Measurement Issues

A key difficulty in identifying the true long-term effects of repeated daytime fasting during pregnancy is that it is impossible for ethical reasons to conduct a true controlled experiment with random assignment. Many of the birthweight studies in the medical literature discussed earlier rely on the assumption that those participants in a study who choose to fast are identical, on average, to those who don't. The most that can be done in these studies is to carefully try to match participants on observable characteristics. One can never be certain however, that fasters differ from non-fasters on the dimension of some unmeasured characteristics. These studies also must rely on small samples that may be unrepresentative, covering only a particular hospital or a particular city.

In contrast, our research design exploits differences in the timing of Ramadan across years on very large representative samples. We measure the average effect of fasting in the Muslim population under the assumption that the composition of who is pregnant during Ramadan compared to who is pregnant outside of Ramadan is similar. The key advantage to our approach is that at any given point in time we do not need to worry about whether fasters and non-fasters within our Muslim population are similar say, with respect to age, education, health or even unobserved behaviors. That is, even if fasters are different from non-fasters we can still identify *average* effects over the entire Muslim population. On the other hand, our approach assumes that parents with particular charateristics that might affect the outcome of interest do not systematically time pregnancy around Ramadan. If for example, better educated parents worry more about the effects of fasting than less educated parents, they might deliberately seek to avoid pregnancy during Ramadan. This could create a spurious relationship between exposure to Ramadan and long-term outcomes.

We address this by showing that on observable characteristics, we do not see differences between parents whose children are *in utero* during Ramadan versus those who aren't. We also think our identifying assumption is sensible for several reasons. First, it is probably difficult to time pregnancy around a narrow window of three months to completely avoid Ramadan. Second, parents who wish to avoid pregnancy during Ramadan can always have the mother take the special dispensation. Third, the fact that Ramadan follows the lunar calendar and falls throughout the year, mechanically avoids many of the systematic selection mechanisms concerning fertility timing.

There are several limitations to our approach that could prevent us from detecting efffects even if such effects exist. One possibility is that maternal nutrition might be most affected before mothers *learn* that they are pregnant. In that case we might expect any negative effects to be present during the first month or two of gestation, roughly eight or nine months before one's birth month. As we noted earlier, fasting among pregnant Muslim women across a range of countries appears to be quite common even in the later stages of gestation. Nonetheless we cannot be certain that this is true in our samples.

In our main analysis with the Uganda data, we also do not know gestation length. If poor nutrition induced by Ramadan reduces gestation length, for example, then we will mismeasure the timing of Ramadan relative to birth month.[16] Finally, with the Uganda and Indonesia Census data we do not know exact birth date which also adds measurement error. For example, for an individual born near the end of the month, the conception month could be eight months prior to the birth month not nine months prior to the birth month.[17] Interestingly, there is evidence that mean gestation length for Ugandans during our sample period is actually two weeks longer than for those born in the U.S. or England

[16] In future drafts we hope to use our Michigan sample to better understand the effects of fasting on gestation length.

[17] To illustrate this concretely, if someone was born on July 30th 1941 and their gestation length was 266 days (the average gestation length) then they would have been conceived on November 6th, 1940. Since Ramadan took place from October 3rd 1940 through November 2nd 1940, such an individual would have had no actual prenatal exposure to Ramadan. However, they would have been coded as having a high level of Ramadan exposure nine months prior to their birth month (October).

(Scotland 1956). Therefore it could be the case that someone born early in the month may have been conceived 10 months earlier. These potential measurement problems likely bias our estimates toward zero, so if anything, our estimates will probably understate the true effects. In addition since only a fraction of pregnant mothers actually fast our estimates should be inflated by the inverse of the fasting rate in order to estimate the average effect in the population.

Our research design also provides two control groups. First, we should not expect to see any effects for muslims not in utero during Ramadan. This will be reflected in our estimates of the coefficient for those "not in utero." Second, since there is no *a priori* reason why Ramadan should affect non-muslims we should not expect to see significant effects for non-muslims. One reason we might see "false positives" (effects on non-muslims) is if for cultural reasons non-Muslims in a predominantly Muslim region or country fast for cultural reasons. This might be an issue for example, in Indonesia. In addition, if the sample of cohorts is relatively small, then it may be difficult to disentangle Ramadan effects from seasonal effects.

This is potentially a concern in our Michigan data which covers 17 birth years from 1989 to 2005. Over this time Ramadan covered about 6-7 months of the calendar year. In 1989 Ramadan began in April and ended in May. By 2005 Ramadan began in October and ended in November. This implies for example, that those born in March through May were never exposed to Ramadan early in pregnancy. As it turns out, mean birthweight levels are higher for our control group of non-Arabs born in April and May. If there is not sufficient seasonal variation in Ramadan, one might worry that this could induce a spurious negative relationship between Ramadan exposure and birthweight even in the control group. As it turns out we do not find such an association for non-Arabs as we will show later.

In discussing the results it should also be kept in mind that 5 percent of the outcomes we observe will be significant at the 5 percent level simply by chance. In addition, since we have the universe of births in Michigan, a 10 percent sample of the Uganda population and nearly the entire population of Indonesia we are also likely to have enough precision to detect statistically significant effects that are quantitately small. This will particularly be the case for non-Arabs in Michigan and non-Muslims in Uganda, each of whom constitute the vast majority of their respective samples.

Finally, it is conceivable that any effects we do detect could be related to birth cohort effects (birth month and birth year interactions in the case of Uganda and Indonesia) that we are not controlling for. These might be due to natural disasters or a particular infectious disease that spiked during a particular point in time that are simply coincident with the timing of Ramadan in one particular year. Therefore, it is important that we also visually inspect the data for outliers and carefully examine the robustness of the results to alternate treatment of outliers. These could also show up as false positives for non-Muslims.

4 Michigan Results

Our analysis is focused primarily on birthweight effects since this is considered the key marker or correlate with future health outcomes in the fetal origins literature. We estimate birthweight effects using three approaches. The first approach uses the exact date of birth of each individual to match them to measures of days of Ramadan exposure at each month post-conception. We do this by going backwards from the birth date in 30 day increments and using *daily* exposure measures from 30 days prior to birth to 270 days prior to birth.[18]

The second approach also utilizes the exact birthdate to match individuals to our measure that scales number of daylight hours in the subsequent 30 days that overlapped with Ramadan relative to the maximum number of possible daylight hours. If the effects vary with the length of the fast then the coefficient should be larger with this measure. Our

[18] Our data does contain information on the self-reported day of the last menstrual period (lmp) for a portion of the sample and another variable for reported gestation (in weeks). We plan to incoporate these measures into our analysis in future drafts of the paper. This will potentially also allow us to examine the effects of Ramadan exposure on gestation length.

third approach mimics what we can do with our Census samples where we only know month of birth. Here we match individuals to the *rampct* measure for each of the 9 months prior to birth.

In addition to birthweight, we also examine the 5 minute apgar score using the daylight hours exposure measure. The apgar score combines five factors (heart rate, breathing, activity and muscle tone, grimace response or "reflex irritability" and appearance as determined by skin coloration) that are used to evaluate the condition of the newborn. Each factor is scored on a scale of 0 to 2. These five factors are added together to calculate the Apgar score which ranges from 0 to 10.

The results are shown in Table 2. The first set of columns shows that among mothers of Arab descent, birthweight is lower for babies who were *in utero* during Ramadan during five of the gestation months when we use *exppct*, our measure of daily exposure. The magnitude of the effects are modest at about 35 to 40 grams or only about 1.5 percent effect evaluated at the mean. Still this is about a fifth of the 200 gram gap in birthweight commonly atributed to smoking and more than third of the black-white gap[19]. Each of these effects were also signficant at the 5 percent level. Overall, the coeffiicient on birthweight for Arab infants who were not in utero is 11.1, which is statistically significant at the 10 percent level. No effects of a similar magnitude are found for babies of non-Arab ancestry.

In the second set of columns we include information on daylight hours. We find that the effect size now increases as might be expected. With this measure it appears that exposure very early in pregnancy is associated with the largest birthweight effects. Specifically, exposure to Ramadan during the summer months when the fasting day is longer (about 15 hours) is associated with a decline in birthweight of about 60 grams. In the third set of columns we move to using exposure measures based only on birth month. With this coarser measure, the effect is now evident only in three cases, (8, 5 and 3 months prior to birth) and the effect in the first month since conception is now weaker and statistically insignificant

[19] See https://content.nejm.org/cgi/content/abstract/337/17/1209?ck=nck

while the effect in the second month since conception is now much stronger at -52 grams.

For apgar scores we find four cases of statistically significant negative effects for babies of Arab ancestry. While these are all extremely small effects relative to the mean apgar score, they are highly significant. We again find that there is a positive effect among those with no in utero exposure. However, this is significant only at the 12 percent level. Overall, the birthweight effects are suggestive that fasting during Ramadan is affecting the intrauterine environment.

5 Uganda Results

5.1 Disability Outcomes

We begin by showing the pooled results for disability outcomes in Table 3A. In the top panel we show the effects for muslims and in the bottom panel we show non-muslims. Since the average rate of disability is only between 3 and 4 percent we have multiplied the coefficients and standard errors by 100 so that the tables are easier to read. The effects are therefore measured in units of percentage points. In the first column we show the effects of Ramadan exposure in the 9 months preceding birth on the incidence of a disability. Our main finding is a statistically significant positive effect for muslims born 9 months after Ramadan suggesting a link between exposure to Ramadan early in pregnancy and compromised health. The point estimate is 0.819 (*p-value*= 0.02). Given the mean disability rate of 0.38, the magnitude of the effect is large at 22 percent. The estimate for non-muslims is close to zero at -0.023 and is fairly precisely estimated. We find that no other month prior to birth is statistically significant.

Looking across specific types of disability, the effects on the incidence of mental or learning disability during the first month of pregnancy is particularly large and statistically significant with a point estimate of 0.250 (*p-value* = 0.001) from a mean rate of 0.138 suggesting that the occurence of Ramadan early in preganancy nearly doubles the likelihood of mental retardation. We also find that the incidence of sight/blindness, hearing/deafness and disabilities of the lower extremities are higher for those born 9 months after Ramadan. Specifically, using this sample the magnitude of the effects relative to those not in utero are 33 percent for blindness (p-value 0.07); 64 percent for deafness (*p-value* = 0.04); and 27 percent for lower extremities (*p-value* = 0.11). Consistent with the Ramadan hypothesis, we find point estimates of around zero for all of these outcomes (in month nine) for non-muslims.

We also estimate statistically significant effects in a few other gestation months and for upper extremities for non-muslims. This is not so surprising in that we should expect about 5 percent of our estimates to be signficant purely by chance. Also, for non-muslims the statistically significant effects are quantitatively smaller. The fact that we find quantitatively very large effects in month 9 that are consistent across a range of outcomes for Muslims is one piece of evidence that suggests that the effects are not spurious. The fact that these effects are found during the first month after conception, before mothers may be aware of their pregnancy, also lends credibility to the estimates. We will also present further evidence when we examine the causes of disability that suggests that what we are finding are not purely due to a chance coincidence with the timing of Ramadan. Nevertheless, we think that it is important to inspect the data visually and to perform robustness checks to ensure that idiosyncratic cohort effects are not driving our results.

When we look at the results separately by sex in tables 3B and 3C, we find that several of the point estimates of the disability outcomes that were significant for the pooled sample are similar for both men and women. However, with the smaller samples, some are no longer significant at the 5 percent level. The estimates for the incidence of disability for those born nine months after Ramadan are 0.553 for men and 1.024 or more than a full percentage point, for women. The latter estimate suggests a 31 percent effect relative to the mean disability rate of 3.27 percent for women. The estimates for blindness and mental disabilities are reasonably similar for both men and women, with the latter statistically significant for both men and women. There is divergence by sex in deafness and lower extremities. For men, exposure to Ramadan during the first month of gestation is associated with a 0.4 percentage point increase in deafness (*p-value* = 0.02) or a 98 percent greater likelihood. For women the point estimate for month nine is close to zero. Interestingly, women are 0.28 percentage points more likely to be deaf if they had Ramadan exposure 8 months prior to birth, however, this is significant only at the 7 percent level. In contrast women born nine months after Ramadan have more than seven tenths of a percentage point greater likelihood of a disability related to a lower extremity (*p-value* = 0.01), a 66 percent increase evaluated at the mean. The point estimate for men is actually slightly negative. The one effect that is dramatic for both men and women is the elevated rates of mental disabilities. For women this is significant at the 1 percent level.

5.2 Causes of Disability

In Table 4 we look at the origins of disability that are identified in the Census for the pooled sample of men and women. We group these factors by their expected relationship with prenatal nutrition. We think that disabilities that arise from accidents or war injuries should not at all be related to maternal fasting during Ramadan. On the other hand, the fetal origins hypothesis suggests that the impacts of poor prenatal nutrition might only be manifested later in life. This would be consistent with those who report "aging" as the source of a disability. Since poor maternal nutrition might be related to disease (e.g. diabetes) or perhaps lower resistance to disease, respondents who report disabilities due to disease could plausibly be related to the timing of Ramadan. Finally, how maternal nutrition affects congenital disabilities (those present at birth), is not clear-cut. If the disability is purely hereditary then we would not expect Ramadan exposure to matter. However, if the intra-uterine environment somehow causes a disability to be present at birth or interacts with genetic factors, then maternal fasting might be associated with congenital disabilities.

Looking first at accidents and war injuries we find no statistically significant effects for muslims or non-muslims in any gestation month. We take some comfort from that the fact these appear to be unrelated to the elevated rates of disability experienced by those who were in their first month of gestation during Ramadan.

We next turn to causes that are plausibly linked to prenatal nutrition. First we find a strongly suggestive result for aging. Muslims born nine months after Ramadan, have an increased incidence of disabilities due to aging of 0.37 percentage points (*p-value* = 0.006). This represents a 71 percent effect evaluated at the sample mean. This result is consistent with the fetal origins hypothesis and suggests that our main finding with respect to disabilities is not spurious. With the pooled sample we find no effects linking the occurence of Ramadan during gestation to disabilities that have origins in disease or that are congenital.

To summarize the main findings with respect to the disability outcomes we find that i) exposure to Ramadan during the first month of pregnancy raises the likelihood of a long-term disability by about 20 percent with even stronger effects for women, ii) both men and women in these cohorts have higher overall disability rates, higher rates of blindness and mental disabilities, iii) men exposed to Ramadan in the first gestation month are more likely to be deaf while for women exposure during the second month is associated with deafness, iv) women with first gestation month exposure are also more likely to experience disabilities of the lower extremities. v) first month exposure to Ramadan appears to be linked to disabilities that occur gradually and are consistent with the fetal programming hypothesis.

5.3 Human Capital and Labor Market Outcomes

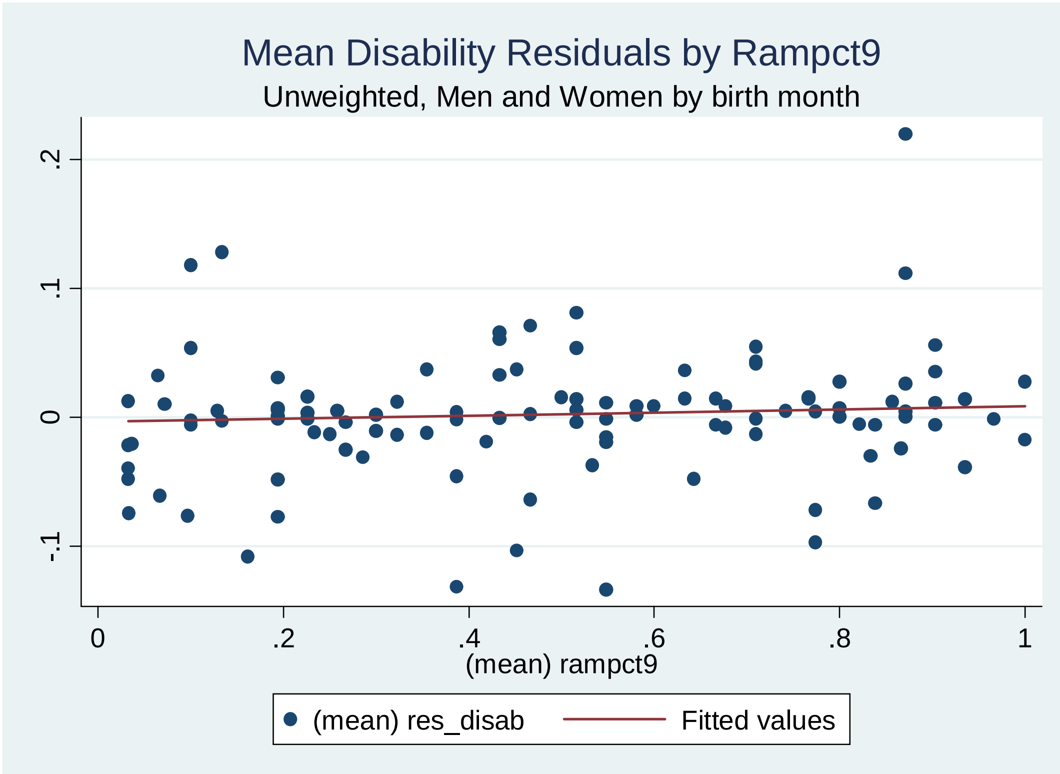
Table 5 shows the results for human capital and labor market outcomes for the pooled sample. For Muslims we find only 2 instances of effects that are significant at the 5 percent level. Those born 5 months after Ramadan have lower employment rates of about 1.8 percentage points which is less than a 3 percent effect size relative to the mean. However, it also appears that among the same cohort, that they are 1.2 percentage points less likely to be employed in elementary occupations, which could be interpreted as a positive outcome. We find no statistically significant effects that associate greater Ramadan exposure with higher illiteracy or lower schooling. In fact those born 8 months after Ramadan appear to have *higher* human capital levels by both of these measures –but the effects are only signficant at the 10 percent level. It is worth pointing out however, that the sizes of these effects, however, are quite small. For example, the increase in years of schooling for these individuals is only about a tenth of a year, or 1.6 percent of the sample mean.

In the bottom panel, we show the effects on non-muslims. Here we find a total of seven instances of statistically significant effects across the outcomes. However, the magnitude of the point estimates are very small and in every case are within a standard error of the coefficient estimates for muslims. In other words, if we had the same precision for non-muslims that we have for muslims, none of the point estimates would be significant. For example, those born 4 months after Ramadan have about five hundredths of a year more schooling which is less than 1 percent higher than the mean.

In other specifications (not shown) that estimated these equations separately by sex we found that the positive effects of Ramadan exposure 8 months before birth on reducing illiteracy and school attendance was much larger for men than with the pooled sample. We found no such effects for women or for non-muslims. These findings appears to raise an interesting question, why do we find a positive effect of exposure to Ramadan during the second month of gestation on some human capital outcomes for men but not women? We discuss this puzzle in more detail in 5.6.

5.4 Cohort Outlier Analysis

One concern is whether we are picking up any "cohort" effects that occur in a specific year and month of birth that might simply be coincident with prenatal exposure to Ramadan in



a particular gestation month.[20] Therefore, we conduct some additional sensitivity analysis for selected outcomes and also inspect the data visually to ensure that the results are not driven by idiosyncratic birth month effects. We begin by looking at the estimated effects on disability found for those born 9 months after Ramadan using the pooled sample (Table 3A). In order to view the data in a way that facilitates the visual identification of cohort effects we first regress our outcomes on all the covariates except for the Ramadan exposure measures and collect the residuals. We then aggregate the residuals by the 654 months of birth for which we have valid data. We then chart the mean residuals against our *rampct9* measure in Figure 2.[21] This is the relationship that when weighted by the sample size in each cohort cell, underlies our regression estimates.

While it is not easy to see visually, there is a slight upward slope to the line consistent

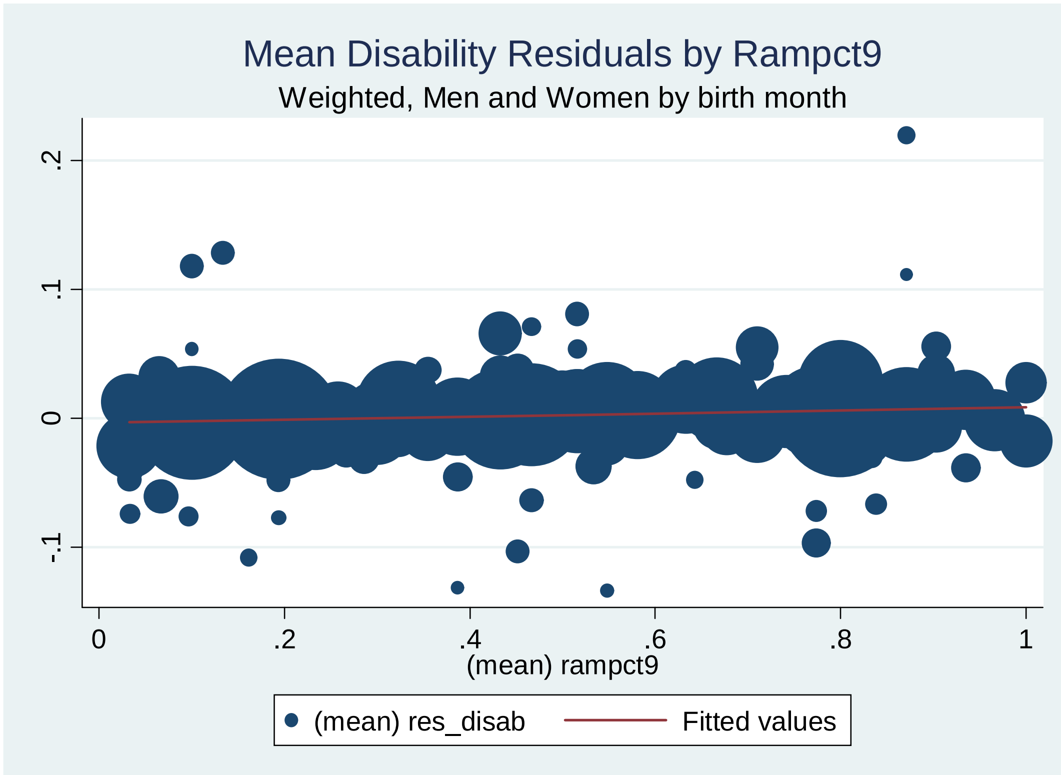
[20] Since our source of variation in Ramadan exposure is at the level of birth month we cannot simultaneously control for birth month effects and identify a Ramadan effect.

[21] We have removed datapoints for which rampct9 = 0 to simplify the the figure, all of the statistical results include these datapoints.

with the findings presented earlier. While it is evident that there are some outliers, these actually represent very few individuals in our sample. For example, there is one birth cohort where the mean disability residual is greater than 2 and for whom the fraction of Ramadan exposure 9 months before birth is greater than 0.8. However, when the data is weighted by the number of individuals in the birth month, the outliers receive relatively little weight. This is shown below in Figure 3, where the size of the circles representing the datapoints are weighted. In order to confirm this we have run our regressions of the disability residuals on *rampct9* both with and without outliers. Here we simply defined outliers as those birth months with mean residuals with absolute values greater than 1. This removes a total of 52 cohorts. The results are shown in Table 6. The coefficient with the outliers is 0.745, which corresponds to the estimate in Table 3A of 0.819. Without the outliers, the coefficient only falls slightly to 0.738. We also conduct a similar sensitivity check with mental disability in column 2 and find that removing outlier cohorts actualy raises the point estimate from 0.160 to 0.184. Not surprisingly, perhaps, the standard errors are much lower without the outliers.

5.5 Effects on the Sex Ratio

We also investigate whether compromised prenatal nutrition due to Ramadan fasting may change the sex ratio (the number of males relative to females). Trivers and Willard (1973) argued that evolution would favor modifications of the offspring sex ratio in response to the maternal condition – parents in good condition would have more sons and those in poor condition more daughters. One proposed mechanism by which adjustment to the sex ratio may take place is through the nutritional status of the mother while pregnant Cameron (2004). Roseboom et al. (2001) found that prenatal exposure to the Dutch famine of 1944-45 reduced the sex ratio of live births. Similarly, Almond, Edlund, Li, and Zhang (2007) found that cohorts *in utero* during the height of the 1959-61 famine in China had lower sex ratios in adulthood.



We investigate the possibility of sex selection in several ways. First we take sex as a dependent variable using our current statistical framework (i.e. we first remove birth year, seasonality and location effects and regress the residuals on occurrence of Ramadan 1 to 9 months before birth). Second we aggregate the data by birth month and calculate population counts by gender and construct a sex ratio of females to males. We regress these on our Ramadan exposure measures where the regressions are weighted by the sample size of the cells. Third, we regress the aggregate population counts by gender on our Ramadan measures to see the underlying patterns behind the sex ratios.

The results are shown in Table 7. In the first column we use the microdata and show the results when being female as an adult is the outcome. We find strong evidence that there are more muslim female adults among the population that was *in utero* during Ramadan. We first note that all nine months have positive signs. In contrast, for those not in utero (*niu*) during Ramadan, the coefficient is negative and statistically significant at the 5 percent level. We find statistically significant effects when Ramadan occurs 3, 4, 6, 8 and 9 months prior to birth. For non-muslims, months 5 and 6 are statistically significant only at the 10 percent level but are of opposite signs and are quite small. Among non-Muslims, those who were not *in utero* during Ramadan have a coefficient close to zero that is precisely estimated.

In the second column we use the aggregated data to construct the ratio of females to males. We find that with this measure the magnitudes of the effects are much more striking. As before, every gestational month has a positive coefficient and the same months are statistically significant. For example, for those exposed to Ramadan three months before birth the effect is to raise the female/male ratio by about 10 percent (p-$value = 0.007$). The coefficient on not in utero is negative and highly significant. The sex ratio of females to males among those not *in utero* is about 6 percent lower. We also note that among non-Muslims the coeffiecient on those not in utero is again not signficiant. Also, while all of our effects on Muslims are also evident if we estimate the male/female ratio (not shown), this is not the case with non-Muslims. For non-Muslims, the effects on the male/female ratio in month 5 are no longer significant if we change the outcome measure.

Although these effects do not appear to be quite as large during the second month of gestation, the reduced number of males may be related to the observed positive human capital effects from Ramadan exposure eight months before birth. If fetuses of marginal health do not survive early in pregnancy this might make the remaining fetuses that do survive gestation appear to be have higher outcomes than average.

5.6 Selective Timing of Conceptions Around Ramadan

A key assumption of the identification strategy is that the composition of Muslim parents does not change systematically by their children's exposure to Ramadan in utero. One might be concerned for example, if individuals of higher socioeconomic status seek to avoid having preganancies overlap with Ramadan by timing conceptions during the two or three months just after Ramadan. Another concern could be that the prohibition against sex during daytime hours might affect fertility patterns in such a way as to induce the patterns that we observe. For example if only individuals of low socioeconomic status or poor health, conceived during Ramadan this might result in higher rates of disability among those born nine months after Ramadan but might be unrelated to prenatal nutrition. This could be the case if for example, religious practice was positively associated with social status. We might also be more generally concerned that fertility patterns change either just before or just after Ramadan. Those conceived just after Ramadan, of course would not be in utero during Ramadan while those conceived just before Ramadan would be born roughly 8 months after the end of Ramadan.

We address these concerns in several ways. First, we show how the aggregate population counts for each gestation month in our Uganda sample are related to Ramadan exposure. It is important to note that this exercise could confound the birth rate with subsequent mortality in these cohorts. Under the (possibly strong) assumption that there is no difference in mortality rates due to Ramadan exposure, this will be informative about birth rate differences. Again we have first removed birth year effects and seasonality effects. The results are presented in the third column of Table 7. Here we have taken the log of the population so that the coefficents are approximately equal to percentage effects and are comparable between muslims and non-muslims. We find no striking differences between muslims and non-muslims. For both groups, the *niu* term is close to zero and statistically insignificant suggesting that the total birth rate is not different for those with fetal exposure during Ramadan in either group. We also note that for 6 of the 9 gestational months the signs are the same.

For muslims we find that only one month has a statistically significant effect relative to the timing of Ramadan. Compared to those not exposed to Ramadan *in utero*, there are about 8.5 percent fewer muslim births in months where Ramadan took place 3 months before birth. However, we also find a negative effect, albeit a smaller one, for non-muslims in the same cohorts suggesting that this might be a common pattern unrelated to religious practice and may be driven by cohort effects. This is even more apparent when we compare exposure to Ramadan 5 months before birth, across the two groups. For both muslims and non-muslims, month five has a very similar coefficient (0.069 and 0.072) . For non-muslims this is significant at the 2 percent level and for muslims this significant at the 13 percent level.

What is also interesting for our analysis is that there is no evidence that conceptions rise in the month before Ramadan and fall in the month of Ramadan. If we assume a gestation length of nine months then those conceived in the month before Ramadan would be exposed to Ramadan in the second gestation month or 8 months before birth and those conceived in the month of Ramadan would be exposed to Ramadan 9 months before birth. We find that that the point estimates for both *rampct9* and *rampct8* are close to zero for muslims and the difference is statistically insignificant.

In addition we can directly observe the human capital levels of the parents whose children were conceived around Ramadan to see if there is evidence of selective mating. In order to do this analysis we use a sample of children aged less than 18 who are living at home and report being a son or daughter of the household head. It should be noted that this sample differs in several important ways from the sample of adults used thus far. The children cover more recent birth cohorts (1984-2002) where the patterns of behavior of parents around Ramadan might be different than that experienced by those born from the 1920s to the 1960s. Second the shorter time span makes us less confident that we can adequately control for seasonal effects. Recall that we need 32 consecutive birth year cohorts in order for Ramadan to have occured throughout the year.

The results of this analysis are shown in Table 8. Specifically we show how illiteracy, years of schooling and disability rates of the household head and the head's wife vary with the Ramadan exposure of the child. We note that few outcomes are statistically significant and there is little evidence to suggest that lower than average human capital parents conceive during Ramadan (9 months prior to the child's birth). Nor is their evidence of selective conceptions before Ramadan (i.e. Ramadan takes place 8 months before birth).

In future drafts we will show the same kind of analysis with the Michigan dataset.

6 Indonesia Results

In future drafts we plan to examine human capital outcomes, fertility outcomes and the effects on sex ratio from the Indonesian Census.

7 Conclusion

[To be completed]

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Table 1A: Summary Statistics for Uganda Census Sample

	Muslim			Non-Muslim		
	mean	s.d.	N	mean	s.d.	N
female	0.494	0.500	81197	0.498	0.500	643300
age	34.546	12.675	81197	36.697	13.907	643300
illiterate	0.304	0.460	78990	0.356	0.479	626473
years of schooling	6.944	3.269	60117	6.797	3.599	449968
no schooling	0.247	0.431	80142	0.290	0.454	635282
employed	0.660	0.474	74348	0.631	0.483	581842
elementary occupation	0.042	0.200	46284	0.042	0.200	347248
disability	0.038	0.191	80924	0.052	0.222	640825
blind/vision impaired	0.011	0.102	80922	0.015	0.121	640789
deaf/hearing impaired	0.004	0.062	80923	0.006	0.078	640781
mute/speech impaired	0.001	0.030	80921	0.001	0.038	640780
lower extremities	0.012	0.111	80921	0.016	0.126	640794
upper extremities	0.004	0.062	80921	0.006	0.075	640779
mental/learning	0.001	0.037	80921	0.002	0.041	640777
psychological	0.001	0.038	80921	0.002	0.045	640776
epilepsy	0.001	0.023	80921	0.001	0.031	640777
rheumatism	0.001	0.030	80921	0.002	0.039	640776
congen	0.005	0.070	80921	0.006	0.076	640778
disease	0.020	0.141	80924	0.028	0.166	640803
accident	0.006	0.074	80921	0.008	0.088	640782
occupational injury	0.005	0.072	80921	0.007	0.086	640786
war¨injury	0.001	0.027	80921	0.001	0.036	640777
aging	0.005	0.072	80921	0.007	0.086	640786
mo1	0.105	0.306	81197	0.096	0.294	643300
mo2	0.076	0.265	81197	0.075	0.263	643300
mo3	0.072	0.258	81197	0.072	0.259	643300
mo4	0.110	0.313	81197	0.106	0.308	643300
mo5	0.070	0.256	81197	0.070	0.256	643300
mo6	0.102	0.302	81197	0.105	0.307	643300
mo7	0.094	0.292	81197	0.098	0.298	643300
mo8	0.079	0.269	81197	0.083	0.275	643300
mo9	0.079	0.269	81197	0.081	0.272	643300
mo10	0.078	0.268	81197	0.077	0.267	643300
mo11	0.069	0.253	81197	0.069	0.253	643300
mo12	0.067	0.250	81197	0.068	0.251	643300
rampct1	0.081	0.215	81197	0.081	0.216	643300
rampct2	0.079	0.214	81197	0.079	0.215	643300
rampct3	0.077	0.211	81197	0.078	0.212	643300
rampct4	0.084	0.219	81197	0.083	0.218	643300
rampct5	0.086	0.223	81197	0.085	0.221	643300
rampct6	0.084	0.217	81197	0.083	0.217	643300
rampct7	0.087	0.222	81197	0.085	0.221	643300
rampct8	0.090	0.226	81197	0.089	0.226	643300
rampct9	0.087	0.221	81197	0.087	0.221	643300

Table 1B: Summary Statistics for Uganda Census Sample, Men

	Muslim			Non-Muslim		
	mean	s.d.	N	mean	s.d.	N
age	35.374	12.973	41074	37.113	13.979	322912
illiterate	0.215	0.411	40118	0.243	0.429	315895
years of schooling	7.213	3.316	33527	7.215	3.611	257216
no schooling	0.169	0.374	40551	0.190	0.393	318951
employed	0.769	0.422	37908	0.717	0.450	294123
elementary occupation	0.056	0.231	27613	0.059	0.235	199811
disability	0.043	0.203	40933	0.058	0.234	321580
blind/vision impaired	0.011	0.106	40932	0.016	0.124	321559
deaf/hearing impaired	0.004	0.064	40933	0.006	0.079	321557
mute/speech impaired	0.001	0.035	40932	0.002	0.042	321558
lower extremities	0.014	0.118	40932	0.019	0.135	321567
upper extremities	0.005	0.073	40932	0.007	0.084	321556
mental/learning	0.002	0.040	40932	0.002	0.045	321555
psychological	0.002	0.041	40932	0.002	0.048	321555
epilepsy	0.001	0.026	40932	0.001	0.033	321555
rheumatism	0.001	0.026	40932	0.001	0.038	321555
congen	0.006	0.077	40932	0.007	0.082	321556
disease	0.021	0.144	40933	0.029	0.169	321568
accident	0.009	0.092	40932	0.011	0.105	321561
occupational injury	0.004	0.067	40932	0.007	0.081	321557
war¨injury	0.001	0.037	40932	0.002	0.046	321556
aging	0.004	0.067	40932	0.007	0.081	321557
mo1	0.111	0.314	41074	0.100	0.300	322912
mo2	0.075	0.264	41074	0.076	0.266	322912
mo3	0.073	0.259	41074	0.072	0.259	322912
mo4	0.112	0.316	41074	0.107	0.309	322912
mo5	0.069	0.253	41074	0.071	0.256	322912
mo6	0.100	0.300	41074	0.106	0.308	322912
mo7	0.095	0.293	41074	0.097	0.296	322912
mo8	0.078	0.268	41074	0.080	0.272	322912
mo9	0.078	0.268	41074	0.079	0.269	322912
mo10	0.079	0.270	41074	0.078	0.268	322912
mo11	0.068	0.251	41074	0.068	0.252	322912
mo12	0.063	0.243	41074	0.067	0.249	322912
rampct1	0.081	0.216	41074	0.081	0.217	322912
rampct2	0.079	0.215	41074	0.080	0.216	322912
rampct3	0.077	0.211	41074	0.079	0.213	322912
rampct4	0.084	0.219	41074	0.084	0.219	322912
rampct5	0.086	0.223	41074	0.085	0.221	322912
rampct6	0.083	0.217	41074	0.084	0.218	322912
rampct7	0.087	0.223	41074	0.086	0.221	322912
rampct8	0.088	0.224	41074	0.089	0.226	322912
rampct9	0.085	0.219	41074	0.086	0.221	322912

Table 1C: Summary Statistics for Uganda Census Sample, Women

	Muslim			Non-Muslim		
	mean	s.d.	N	mean	s.d.	N
age	33.699	12.305	40123	36.279	13.822	320388
illiterate	0.395	0.489	38872	0.471	0.499	310578
years of schooling	6.606	3.177	26590	6.239	3.504	192752
no schooling	0.326	0.469	39591	0.390	0.488	316331
employed	0.547	0.498	36440	0.542	0.498	287719
elementary occupation	0.020	0.140	18671	0.019	0.135	147437
disability	0.033	0.178	39991	0.046	0.210	319245
blind/vision impaired	0.010	0.098	39990	0.014	0.119	319230
deaf/hearing impaired	0.004	0.059	39990	0.006	0.077	319224
mute/speech impaired	0.001	0.024	39989	0.001	0.034	319222
lower extremities	0.011	0.103	39989	0.014	0.116	319227
upper extremities	0.002	0.050	39989	0.004	0.065	319223
mental/learning	0.001	0.034	39989	0.001	0.037	319222
psychological	0.001	0.033	39989	0.002	0.041	319221
epilepsy	0.000	0.020	39989	0.001	0.028	319222
rheumatism	0.001	0.034	39989	0.002	0.041	319221
congen	0.004	0.062	39989	0.005	0.070	319222
disease	0.019	0.138	39991	0.027	0.163	319235
accident	0.003	0.051	39989	0.005	0.068	319221
occupational injury	0.006	0.078	39989	0.008	0.091	319229
war¨injury	0.000	0.011	39989	0.000	0.021	319221
aging	0.006	0.078	39989	0.008	0.091	319229
mo1	0.098	0.298	40123	0.092	0.288	320388
mo2	0.077	0.266	40123	0.073	0.261	320388
mo3	0.071	0.257	40123	0.073	0.260	320388
mo4	0.108	0.311	40123	0.104	0.306	320388
mo5	0.072	0.259	40123	0.070	0.255	320388
mo6	0.103	0.304	40123	0.105	0.306	320388
mo7	0.093	0.290	40123	0.100	0.299	320388
mo8	0.079	0.270	40123	0.085	0.279	320388
mo9	0.080	0.271	40123	0.083	0.275	320388
mo10	0.077	0.266	40123	0.077	0.266	320388
mo11	0.070	0.256	40123	0.070	0.255	320388
mo12	0.071	0.257	40123	0.069	0.253	320388
rampct1	0.080	0.214	40123	0.081	0.216	320388
rampct2	0.078	0.213	40123	0.079	0.214	320388
rampct3	0.078	0.212	40123	0.078	0.212	320388
rampct4	0.084	0.219	40123	0.082	0.217	320388
rampct5	0.087	0.222	40123	0.085	0.221	320388
rampct6	0.084	0.218	40123	0.082	0.216	320388
rampct7	0.086	0.220	40123	0.085	0.220	320388
rampct8	0.091	0.227	40123	0.090	0.226	320388
rampct9	0.088	0.223	40123	0.087	0.221	320388

Table 2: Effects of Ramadan Exposure on Birth Outcomes by Months Prior to Birth, Michigan

	Arab Ancestry							
months	*Birthweight*						*Apgar 5 minute*	
prior	Using Birth Date		Using Birth Date		Using Birth Month		Using Birth Date	
to birth	Percent of Days		% of Daylight Hours		Percent of Days		% of Daylight Hours	
1	3.1	(13.8)	3.2	(19.8)	-17.6	(14.0)	-0.05 ***	(0.020)
2	-13.2	(13.6)	-12.9	(19.3)	-20.5	(13.6)	0.00	(0.020)
3	-35.2 **	(14.2)	-46.4 **	(20.2)	-38.9 ***	(14.6)	-0.04 *	(0.021)
4	-31.4 **	(14.2)	-41.7 **	(20.2)	-11.4	(14.4)	0.00	(0.021)
5	-3.2	(14.3)	-4.0	(20.4)	-26.1 *	(14.5)	0.01	(0.021)
6	-36.8 ***	(14.0)	-49.8 **	(20.0)	-20.7	(14.2)	0.01	(0.020)
7	9.0	(13.9)	10.9	(20.0)	-14.4	(14.1)	-0.04 **	(0.020)
8	-40.6 ***	(13.4)	-60.0 ***	(19.3)	-51.9 ***	(13.6)	0.01	(0.020)
9	-36.1 ***	(13.8)	-54.3 ***	(20.4)	-11.7	(14.0)	-0.04 **	(0.021)
not in utero	11.1 *	(6.8)					0.011	(0.007)
N	40815						40753	
	Non-Arab Ancestry							
1	0.5	(2.5)	2.0	(3.4)	-1.1	(2.4)	0.00	(0.004)
2	-0.6	(2.4)	0.4	(3.3)	-3.1	(2.4)	0.01	(0.004)
3	-4.2 *	(2.5)	-5.3	(3.4)	-3.4	(2.5)	0.00	(0.004)
4	-2.4	(2.5)	-3.2	(3.5)	-4.3 *	(2.5)	0.00	(0.004)
5	-4.9 *	(2.5)	-6.0 *	(3.5)	-6.0 **	(2.5)	0.00	(0.004)
6	-1.6	(2.5)	-1.3	(3.5)	-0.3	(2.5)	0.00	(0.004)
7	-3.6	(2.5)	-4.1	(3.5)	-6.6 ***	(2.5)	0.01 *	(0.004)
8	-3.4	(2.4)	-4.3	(3.4)	-3.3	(2.4)	-0.01 *	(0.004)
9	-2.6	(2.5)	-3.5	(3.6)	-2.5	(2.5)	0.00	(0.004)
not in utero	0.7	(1.2)					0.00	(0.001)
N	1542573						1537662	

Notes: *significant at 10% level, ** signficant at 5% level, ***significant at 1% level, s.e.'s in parentheses

Table 3A: Effects of Ramadan Exposure on Disability by Months Prior to Birth, Uganda Census

Muslims

*coefficient *100*

months prior to birth	disability		sight/blind		hear/deaf		lower		upper		mental/learning		psychological	
1	-0.103	(0.366)	0.018	(0.196)	0.086	(0.120)	-0.058	(0.214)	-0.056	(0.121)	0.089	(0.072)	-0.034	(0.073)
2	-0.266	(0.350)	-0.272	(0.187)	0.026	(0.114)	-0.059	(0.205)	0.001	(0.116)	0.144 **	(0.069)	-0.019	(0.070)
3	0.104	(0.364)	0.124	(0.195)	0.099	(0.119)	-0.118	(0.214)	-0.029	(0.121)	0.039	(0.072)	-0.009	(0.073)
4	0.273	(0.352)	0.039	(0.189)	0.072	(0.115)	0.033	(0.206)	0.179	(0.117)	0.117 *	(0.070)	-0.049	(0.070)
5	0.085	(0.348)	-0.004	(0.187)	0.197 *	(0.114)	-0.045	(0.204)	-0.036	(0.115)	0.129 *	(0.069)	-0.058	(0.069)
6	0.197	(0.353)	0.074	(0.189)	0.161	(0.115)	-0.151	(0.207)	0.085	(0.117)	0.100	(0.070)	-0.098	(0.070)
7	-0.132	(0.349)	-0.022	(0.187)	0.130	(0.114)	-0.316	(0.204)	0.077	(0.115)	0.028	(0.069)	0.058	(0.069)
8	0.087	(0.337)	-0.078	(0.180)	0.162	(0.110)	0.057	(0.197)	0.008	(0.112)	0.103	(0.066)	-0.068	(0.067)
9	0.819 **	(0.359)	0.349 *	(0.193)	0.243 **	(0.117)	0.334	(0.211)	-0.071	(0.119)	0.250 ***	(0.071)	-0.098	(0.072)
not iu	0.038	(0.198)	0.032	(0.106)	-0.087	(0.065)	0.052	(0.116)	0.001	(0.066)	-0.091 **	(0.039)	0.036	(0.039)
mean %	3.805		1.057		0.382		1.246		0.392		0.138		0.141	
N	80924		80922		80923		80921		80921		80921		80921	

Non-Muslims

*coefficient *100*

months prior to birth	disability		sight/blind		hear/deaf		lower		upper		mental/learning		psychological	
1	0.208	(0.148)	-0.061	(0.082)	0.035	(0.053)	0.122	(0.085)	0.123 **	(0.051)	0.010	(0.028)	0.023	(0.030)
2	0.039	(0.142)	-0.016	(0.078)	0.065	(0.051)	-0.019	(0.082)	0.015	(0.049)	-0.043	(0.027)	0.036	(0.029)
3	0.003	(0.147)	0.115	(0.081)	-0.018	(0.053)	-0.002	(0.085)	0.003	(0.051)	-0.004	(0.028)	0.010	(0.030)
4	-0.090	(0.144)	-0.030	(0.079)	0.048	(0.051)	-0.010	(0.083)	-0.019	(0.049)	-0.004	(0.027)	-0.017	(0.029)
5	0.209	(0.143)	-0.111	(0.079)	0.051	(0.051)	0.074	(0.082)	0.125 **	(0.049)	0.034	(0.027)	0.006	(0.029)
6	-0.091	(0.144)	0.082	(0.079)	-0.007	(0.051)	-0.082	(0.083)	0.012	(0.049)	-0.017	(0.027)	0.017	(0.029)
7	-0.074	(0.142)	-0.142	(0.078)	-0.006	(0.051)	0.097	(0.082)	-0.038	(0.049)	-0.006	(0.027)	0.010	(0.029)
8	-0.015	(0.137)	-0.043	(0.075)	0.043	(0.049)	0.034	(0.079)	0.096 **	(0.047)	-0.005	(0.026)	-0.028	(0.028)
9	-0.023	(0.146)	-0.052	(0.080)	0.028	(0.052)	-0.039	(0.084)	0.051	(0.050)	-0.037	(0.028)	0.045	(0.030)
not iu	-0.003	(0.080)	0.050	(0.044)	-0.037	(0.029)	-0.008	(0.046)	-0.052 *	(0.028)	0.004	(0.015)	0.009	(0.016)
mean %	5.206		1.493		0.610		1.613		0.565		0.170		0.199	
N	640825		640789		640781		640780		640794		640779		640777	

Notes: *significant at 10% level, ** signficant at 5% level, ***significant at 1% level, s.e.'s in parentheses

Table 3B: Effects of Ramadan Exposure on Disability by Months Prior to Birth, Uganda Census, Men

Muslim Men

months prior to birth	disability		sight/blind		hear/deaf		lower		upper		mental/learning		psychological	
	*coefficient *100*													
1	-0.078	(0.544)	0.161	(0.283)	0.171	(0.173)	-0.021	(0.318)	-0.269	(0.197)	0.148	(0.108)	-0.060	(0.112)
2	-0.695	(0.521)	-0.629 **	(0.271)	0.205	(0.166)	-0.474	(0.305)	0.120	(0.189)	0.121	(0.103)	-0.044	(0.107)
3	0.368	(0.543)	0.365	(0.283)	0.148	(0.173)	-0.311	(0.318)	-0.023	(0.197)	0.015	(0.108)	-0.082	(0.112)
4	0.420	(0.525)	0.162	(0.274)	0.218	(0.167)	-0.259	(0.307)	0.201	(0.190)	0.038	(0.104)	-0.042	(0.108)
5	0.001	(0.518)	0.137	(0.270)	0.250	(0.165)	-0.134	(0.303)	-0.116	(0.188)	0.057	(0.103)	-0.211 **	(0.107)
6	-0.184	(0.527)	0.038	(0.275)	0.129	(0.168)	-0.593 *	(0.308)	-0.068	(0.191)	0.143	(0.105)	-0.196 *	(0.109)
7	-0.369	(0.518)	0.113	(0.270)	0.271 *	(0.165)	-0.620 **	(0.303)	0.011	(0.188)	-0.015	(0.103)	0.019	(0.107)
8	0.092	(0.504)	-0.038	(0.263)	0.054	(0.160)	0.024	(0.295)	0.048	(0.183)	0.020	(0.100)	-0.089	(0.104)
9	0.553	(0.540)	0.430	(0.282)	0.402 **	(0.172)	-0.050	(0.316)	-0.141	(0.196)	0.215 **	(0.107)	-0.133	(0.111)
not iu	0.306	(0.294)	0.085	(0.153)	-0.125	(0.093)	0.277	(0.172)	0.060	(0.107)	-0.047	(0.058)	0.071	(0.061)
mean %	4.324		1.136		0.410		1.405		0.533		0.159		0.171	
N	40933		40932		40933		40932		40932		40932		40932	

Non-Muslim Men

months prior to birth	disability		sight/blind		hear/deaf		lower		upper		mental/learning		psychological	
	*coefficient *100*													
1	0.299	(0.220)	0.034	(0.118)	0.072	(0.075)	0.010	(0.129)	0.196 **	(0.080)	-0.010	(0.043)	0.047	(0.046)
2	0.132	(0.211)	-0.077	(0.113)	0.016	(0.072)	-0.024	(0.124)	0.080	(0.077)	-0.018	(0.041)	0.048	(0.044)
3	0.068	(0.218)	0.191	(0.116)	0.017	(0.075)	-0.122	(0.128)	0.063	(0.080)	-0.011	(0.042)	-0.004	(0.046)
4	-0.123	(0.213)	0.012	(0.114)	0.050	(0.073)	0.017	(0.125)	-0.064	(0.078)	0.016	(0.041)	-0.059	(0.045)
5	0.249	(0.212)	-0.065	(0.113)	-0.054	(0.072)	-0.071	(0.124)	0.271 ***	(0.077)	0.075 *	(0.041)	0.012	(0.045)
6	-0.090	(0.213)	0.049	(0.114)	-0.019	(0.073)	-0.112	(0.125)	-0.006	(0.078)	-0.052	(0.041)	0.044	(0.045)
7	-0.238	(0.211)	-0.264	(0.113)	-0.031	(0.072)	-0.055	(0.124)	-0.058	(0.077)	0.027	(0.041)	0.062	(0.044)
8	0.075	(0.204)	-0.065	(0.109)	-0.019	(0.070)	0.183	(0.119)	0.198 ***	(0.074)	-0.013	(0.040)	-0.047	(0.043)
9	-0.021	(0.217)	-0.142	(0.116)	0.032	(0.074)	-0.147	(0.127)	0.078	(0.079)	-0.023	(0.042)	0.040	(0.046)
not iu	-0.137	(0.120)	0.041	(0.064)	-0.023	(0.041)	-0.026	(0.070)	-0.094 **	(0.044)	-0.001	(0.023)	0.002	(0.025)
mean %	5.795		1.561		0.621		1.858		0.707		0.199		0.233	
N	321580		321559		321557		321558		321567		321556		321555	

Notes: *significant at 10% level, ** signficant at 5% level, ***significant at 1% level, s.e.'s in parentheses

Table 3C: Effects of Ramadan Exposure on Disability by Months Prior to Birth, Uganda Census, Women

Muslim Women

*coefficient *100*

months prior to birth	disability		sight/blind		hear/deaf		lower		upper		mental/learning		psychological	
1	-0.102	(0.487)	-0.149	(0.270)	-0.010	(0.165)	-0.052	(0.287)	0.183	(0.138)	0.024	(0.095)	0.000	(0.092)
2	0.182	(0.465)	0.063	(0.258)	-0.158	(0.157)	0.394	(0.274)	-0.110	(0.132)	0.171 *	(0.091)	0.010	(0.088)
3	-0.136	(0.485)	-0.136	(0.269)	0.031	(0.164)	0.139	(0.285)	-0.016	(0.137)	0.073	(0.095)	0.074	(0.092)
4	0.131	(0.468)	-0.085	(0.260)	-0.058	(0.158)	0.341	(0.276)	0.144	(0.133)	0.199 **	(0.092)	-0.043	(0.089)
5	0.213	(0.464)	-0.163	(0.258)	0.121	(0.157)	0.092	(0.273)	0.058	(0.132)	0.206 **	(0.091)	0.095	(0.088)
6	0.612	(0.469)	0.126	(0.260)	0.202	(0.158)	0.325	(0.276)	0.256 *	(0.133)	0.059	(0.092)	0.010	(0.089)
7	0.102	(0.465)	-0.193	(0.258)	-0.018	(0.157)	0.007	(0.274)	0.155	(0.132)	0.072	(0.091)	0.097	(0.088)
8	0.091	(0.446)	-0.142	(0.247)	0.276 *	(0.151)	0.101	(0.262)	-0.009	(0.126)	0.189 **	(0.087)	-0.042	(0.085)
9	1.024 **	(0.473)	0.241	(0.262)	0.082	(0.160)	0.714 ***	(0.278)	-0.001	(0.134)	0.289 ***	(0.093)	-0.060	(0.090)
not iu	-0.239	(0.264)	0.000	(0.147)	-0.045	(0.089)	-0.204	(0.155)	-0.069	(0.075)	-0.141 ***	(0.052)	-0.002	(0.050)
mean %	3.273		0.975		0.353		1.083		0.248		0.118		0.110	
N	39991		39990		39990		39989		39989		39989		39989	

Non-Muslim Women

*coefficient *100*

months prior to birth	disability		sight/blind		hear/deaf		lower		upper		mental/learning		psychological	
1	0.115	(0.198)	-0.155	(0.113)	-0.006	(0.074)	0.236 **	(0.112)	0.050	(0.063)	0.030	(0.036)	-0.002	(0.039)
2	-0.054	(0.191)	0.051	(0.109)	0.114	(0.072)	-0.013	(0.108)	-0.055	(0.060)	-0.069 **	(0.035)	0.024	(0.038)
3	-0.049	(0.198)	0.045	(0.113)	-0.056	(0.074)	0.125	(0.111)	-0.056	(0.062)	0.005	(0.036)	0.024	(0.039)
4	-0.050	(0.193)	-0.064	(0.110)	0.040	(0.072)	-0.038	(0.109)	0.028	(0.061)	-0.026	(0.035)	0.026	(0.038)
5	0.183	(0.191)	-0.154	(0.109)	0.156 **	(0.072)	0.228 **	(0.107)	-0.024	(0.060)	-0.008	(0.035)	0.002	(0.038)
6	-0.077	(0.193)	0.122	(0.110)	0.004	(0.072)	-0.048	(0.109)	0.032	(0.061)	0.016	(0.035)	-0.009	(0.038)
7	0.115	(0.191)	-0.013	(0.109)	0.023	(0.072)	0.258 **	(0.107)	-0.018	(0.060)	-0.038	(0.035)	-0.041	(0.038)
8	-0.113	(0.183)	-0.020	(0.104)	0.101	(0.069)	-0.122	(0.103)	-0.007	(0.058)	0.002	(0.033)	-0.008	(0.036)
9	-0.019	(0.195)	0.044	(0.111)	0.028	(0.073)	0.073	(0.110)	0.025	(0.062)	-0.052	(0.036)	0.053	(0.039)
not iu	0.127	(0.107)	0.056	(0.061)	-0.048	(0.040)	0.008	(0.060)	-0.009	(0.034)	0.009	(0.020)	0.014	(0.021)
mean %	4.614		1.425		0.599		1.367		0.422		0.140		0.165	
N	319245		319230		319224		319222		319227		319223		319222	

Notes: *significant at 10% level, ** signficant at 5% level, ***significant at 1% level, s.e.'s in parentheses

Table 4: Ramadan Exposure on Disability Causes by Months Prior to Birth, Uganda Census

Muslims (coeff *100)

months prior to birth	*Unrelated to prenatal nutrition*						*Possibly related to prenatal nutrition*					
	accident		occ. injury		war injury		aging		disease		congenital	
1	0.002	(0.144)	-0.086	(0.076)	0.057	(0.053)	0.051	(0.138)	-0.044	(0.271)	-0.116	(0.136)
2	0.161	(0.138)	-0.063	(0.072)	0.021	(0.050)	-0.011	(0.132)	-0.158	(0.259)	-0.225 *	(0.130)
3	-0.090	(0.144)	0.031	(0.075)	0.047	(0.053)	0.110	(0.138)	0.006	(0.270)	0.012	(0.136)
4	0.179	(0.139)	0.018	(0.073)	0.064	(0.051)	0.055	(0.133)	-0.252	(0.261)	0.153	(0.131)
5	0.127	(0.137)	-0.009	(0.072)	-0.085 *	(0.050)	-0.022	(0.132)	0.100	(0.258)	0.084	(0.130)
6	-0.025	(0.139)	0.050	(0.073)	0.043	(0.051)	0.222 *	(0.134)	-0.369	(0.262)	0.210	(0.132)
7	-0.102	(0.137)	-0.063	(0.072)	0.000	(0.050)	-0.034	(0.132)	-0.248	(0.259)	0.131	(0.130)
8	0.042	(0.133)	-0.023	(0.070)	0.001	(0.049)	0.137	(0.127)	-0.025	(0.250)	-0.017	(0.126)
9	-0.060	(0.142)	0.059	(0.074)	0.054	(0.052)	0.373 ***	(0.136)	0.199	(0.267)	0.137	(0.134)
not iu	0.007	(0.078)	0.026	(0.041)	-0.023	(0.029)	-0.108	(0.075)	0.184	(0.147)	-0.049	(0.074)
mean	0.557		0.528		0.074		0.528		2.027		0.496	
N	80921		80921		80921		80921		80924		80921	

Non-Muslims (coeff *100)

months prior to birth	*Unrelated to prenatal nutrition*						*Possibly related to prenatal nutrition*					
	accident		occ. injury		war injury		aging		disease		congenital	
1	0.047	(0.060)	0.029	(0.030)	0.034	(0.025)	-0.050	(0.058)	-0.013	(0.112)	0.124 **	(0.052)
2	0.024	(0.058)	-0.027	(0.029)	-0.022	(0.024)	-0.021	(0.055)	-0.010	(0.108)	0.067	(0.050)
3	0.042	(0.060)	0.014	(0.030)	0.002	(0.025)	-0.011	(0.057)	-0.015	(0.111)	0.007	(0.052)
4	0.019	(0.058)	0.028	(0.029)	-0.027	(0.024)	-0.031	(0.056)	-0.088	(0.109)	-0.029	(0.050)
5	0.029	(0.058)	-0.007	(0.029)	0.007	(0.024)	0.029	(0.055)	0.160	(0.108)	0.039	(0.050)
6	0.028	(0.058)	-0.005	(0.029)	-0.012	(0.024)	0.055	(0.056)	-0.169	(0.109)	-0.005	(0.050)
7	0.048	(0.058)	0.007	(0.029)	0.006	(0.024)	-0.002	(0.055)	-0.112	(0.108)	-0.006	(0.050)
8	-0.024	(0.055)	-0.012	(0.028)	0.027	(0.023)	-0.044	(0.053)	0.057	(0.103)	-0.008	(0.048)
9	0.077	(0.059)	-0.007	(0.030)	0.005	(0.024)	-0.052	(0.057)	-0.058	(0.110)	0.013	(0.051)
not iu	-0.019	(0.033)	-0.012	(0.016)	-0.004	(0.013)	0.043	(0.031)	0.038	(0.061)	-0.027	(0.028)
mean	0.789		0.744		0.131		0.744		2.832		0.583	
N	640782		640786		640777		640786		640803		640778	

Notes: *significant at 10% level, ** signficant at 5% level, ***significant at 1% level, s.e.'s in parentheses

Table 5: Effects of Ramadan Exposure on Human Capital by Months Prior to Birth, Uganda Census

Muslims

months prior to birth	illiterate		yrs of school		no school		employed		elementary occup.	
1	0.005	(0.008)	-0.011	(0.069)	-0.005	(0.008)	0.001	(0.009)	-0.007	0.005
2	0.009	(0.008)	0.069	(0.067)	0.009	(0.007)	-0.002	(0.009)	-0.002	0.005
3	0.002	(0.008)	0.061	(0.069)	-0.002	(0.008)	0.005	(0.009)	-0.003	0.005
4	0.008	(0.008)	-0.045	(0.067)	0.006	(0.007)	-0.001	(0.009)	-0.003	0.005
5	0.012	(0.008)	-0.015	(0.067)	0.005	(0.007)	-0.019 **	(0.009)	-0.013 ***	0.005
6	-0.014 *	(0.008)	0.010	(0.067)	-0.013 *	(0.007)	0.013	(0.009)	0.004	0.005
7	0.007	(0.008)	-0.009	(0.066)	0.001	(0.007)	-0.009	(0.009)	-0.006	0.005
8	-0.015 **	(0.007)	0.119 *	(0.064)	-0.007	(0.007)	-0.001	(0.008)	0.003	0.005
9	0.008	(0.008)	-0.088	(0.068)	-0.004	(0.007)	0.000	(0.009)	-0.005	0.005
not iu	-0.001	(0.004)	0.020	(0.038)	0.002	(0.004)	0.004	(0.005)	0.002	0.003
mean	0.304		6.944		0.247		0.660		0.042	
N	78990		60117		80142		74348		46284	

Non-Muslims

months prior to birth	illiterate		yrs of school		no school		employed		elementary occup.	
1	-0.001	(0.003)	0.078 ***	(0.028)	0.003	(0.003)	-0.009 ***	(0.003)	0.002	0.002
2	-0.002	(0.003)	0.013	(0.027)	0.000	(0.003)	-0.002	(0.003)	-0.003	0.002
3	-0.001	(0.003)	0.073 ***	(0.028)	0.003	(0.003)	-0.009 ***	(0.003)	0.000	0.002
4	0.006 **	(0.003)	0.054 **	(0.027)	0.010 ***	(0.003)	-0.006 *	(0.003)	-0.003 **	0.002
5	0.002	(0.003)	0.020	(0.027)	0.005 **	(0.003)	-0.002	(0.003)	0.003	0.002
6	-0.004	(0.003)	0.005	(0.027)	-0.004	(0.003)	-0.002	(0.003)	0.000	0.002
7	0.002	(0.003)	-0.048 *	(0.027)	0.004	(0.003)	-0.003	(0.003)	0.001	0.002
8	-0.001	(0.003)	0.002	(0.026)	0.000	(0.003)	0.003	(0.003)	-0.002	0.002
9	-0.001	(0.003)	0.002	(0.027)	-0.002	(0.003)	0.001	(0.003)	-0.002	0.002
not iu	0.000	(0.002)	-0.019	(0.015)	-0.003 *	(0.001)	0.004 **	(0.002)	0.001	0.001
mean	0.356		6.797		0.290		0.631		0.042	
N	626473		449968		635282		581842		347248	

Notes: *significant at 10% level, ** signficant at 5% level, ***significant at 1% level, s.e.'s in parentheses

Table 6: Effects of Ramadan Exposure on Various Outcomes for Muslims, Sensitivity to Outlier Cohorts

	Outcome	
	Pooled Disability on rampct9	Pooled Mental Disab on rampct9
with outliers	0.745	0.160
	(0.409)	(0.057)
N	654	654
without outliers	0.738	0.184
	(0.319)	(0.039)
N	604	633

Table 7: Ramadan Exposure on Ugandan Sex Ratios, Population Counts (Excludes Ages ending in zero)

Muslims

months prior to birth	Female		Female/Male Ratio		Total Log Pop Counts		Male Log Pop Counts		Female Log Pop Counts	
1	0.009	(0.010)	0.034	(0.038)	-0.025	(0.047)	-0.031	(0.059)	0.012	(0.065)
2	0.009	(0.009)	0.041	(0.037)	0.025	(0.045)	0.001	(0.056)	0.066	(0.063)
3	0.026 ***	(0.010)	0.104 ***	(0.038)	-0.085 *	(0.046)	-0.148 ***	(0.057)	0.008	(0.064)
4	0.016 *	(0.009)	0.067 *	(0.037)	0.002	(0.045)	-0.030	(0.057)	0.036	(0.064)
5	0.015	(0.009)	0.055	(0.036)	0.069	(0.045)	0.014	(0.057)	0.150 **	(0.064)
6	0.021 **	(0.009)	0.091 **	(0.037)	-0.047	(0.045)	-0.081	(0.057)	0.010	(0.063)
7	0.003	(0.009)	0.008	(0.036)	0.007	(0.045)	-0.055	(0.057)	0.083	(0.063)
8	0.015 *	(0.009)	0.060 *	(0.035)	0.015	(0.044)	-0.034	(0.056)	0.081	(0.062)
9	0.020 **	(0.009)	0.080 **	(0.038)	0.001	(0.047)	-0.030	(0.059)	0.053	(0.065)
niu	-0.013 **	(0.005)	-0.056 ***	(0.021)	-0.005	(0.025)	0.026	(0.031)	-0.055	(0.035)
mean	0.494		1.006		4.205		3.554		3.399	
N	81197		648		648		653		649	

Non-Muslims

months prior to birth	Female		Female/Male Ratio		Total Log Pop Counts		Male Log Pop Counts		Female Log Pop Counts	
1	0.003	(0.003)	0.007	(0.015)	0.031	(0.032)	0.029	(0.032)	0.035	(0.035)
2	0.001	(0.003)	0.006	(0.014)	0.026	(0.030)	0.028	(0.030)	0.024	(0.034)
3	0.003	(0.003)	0.008	(0.015)	-0.022	(0.031)	-0.017	(0.031)	-0.028	(0.034)
4	-0.002	(0.003)	-0.011	(0.014)	0.032	(0.031)	0.038	(0.031)	0.029	(0.034)
5	0.006 *	(0.003)	0.016	(0.014)	0.072 **	(0.031)	0.058 *	(0.031)	0.089 ***	(0.034)
6	-0.006 *	(0.003)	-0.029 **	(0.014)	-0.010	(0.031)	-0.007	(0.031)	-0.012	(0.034)
7	0.000	(0.003)	0.002	(0.014)	-0.009	(0.031)	0.001	(0.031)	-0.021	(0.034)
8	0.001	(0.003)	-0.002	(0.014)	0.007	(0.030)	-0.013	(0.030)	0.033	(0.034)
9	0.002	(0.003)	0.004	(0.015)	0.042	(0.032)	0.053 *	(0.032)	0.026	(0.035)
niu	-0.002	(0.002)	-0.006	(0.008)	-0.028	(0.017)	-0.025	(0.017)	-0.031	(0.019)
mean	0.498		1.001		6.451		5.790		5.717	
N	643300		654		654		654		654	

Notes: *significant at 10% level, ** signficant at 5% level, ***significant at 1% level, s.e.'s in parentheses

Table 8: Parent Human Capital Measures and Children's Exposure to Ramadan

Muslims

months prior to birth	Illiteracy of Head		Illiteracy of Wife		Years of School of Head		Years of School of Wife		Disabled Head		Disabled Wife	
1	0.004	(0.007)	-0.004	(0.008)	-0.080	(0.056)	-0.015	(0.058)	-0.009 ***	(0.003)	0.000	(0.003)
2	-0.002	(0.007)	-0.001	(0.008)	-0.023	(0.053)	-0.086	(0.055)	-0.005	(0.003)	0.000	(0.002)
3	-0.003	(0.007)	0.007	(0.008)	-0.001	(0.054)	-0.041	(0.056)	-0.008 ***	(0.003)	0.002	(0.002)
4	0.005	(0.007)	0.000	(0.008)	0.049	(0.054)	-0.017	(0.056)	0.001	(0.003)	0.002	(0.002)
5	-0.006	(0.007)	0.007	(0.008)	-0.009	(0.055)	0.005	(0.057)	0.002	(0.003)	0.002	(0.002)
6	-0.006	(0.007)	-0.010	(0.008)	0.036	(0.055)	0.013	(0.056)	-0.008 **	(0.003)	0.001	(0.002)
7	0.000	(0.007)	0.009	(0.008)	-0.046	(0.056)	-0.047	(0.058)	0.000	(0.003)	0.005 *	(0.003)
8	-0.005	(0.007)	-0.010	(0.008)	0.045	(0.055)	-0.018	(0.057)	-0.008 **	(0.003)	-0.001	(0.003)
9	-0.006	(0.007)	0.005	(0.009)	0.024	(0.058)	-0.016	(0.060)	0.000	(0.003)	0.004 *	(0.003)
niu	0.001	(0.003)	0.000	(0.004)	0.001	(0.026)	0.019	(0.026)	0.003 **	(0.002)	-0.001	(0.001)
mean	0.248		0.393		6.758		6.214		0.040		0.019	
N	90087		76491		72392		55072		91661		78221	

Non-Muslims

months prior to birth	Illiteracy of Head		Illiteracy of Wife		Years of School of Head		Years of School of Wife		Disabled Head		Disabled Wife	
1	-0.006 **	(0.003)	0.001	(0.003)	0.003	(0.024)	0.008	(0.025)	0.001	(0.001)	0.000	(0.001)
2	-0.003	(0.003)	0.000	(0.003)	-0.020	(0.022)	0.005	(0.023)	0.002	(0.001)	0.000	(0.001)
3	-0.005 **	(0.003)	-0.004	(0.003)	0.027	(0.023)	0.033	(0.023)	0.001	(0.001)	0.001	(0.001)
4	0.000	(0.003)	0.002	(0.003)	0.007	(0.022)	0.023	(0.023)	0.001	(0.001)	0.000	(0.001)
5	-0.005 *	(0.003)	0.000	(0.003)	-0.007	(0.023)	0.008	(0.024)	0.000	(0.001)	0.000	(0.001)
6	-0.002	(0.003)	-0.002	(0.003)	0.021	(0.023)	0.026	(0.024)	0.001	(0.001)	0.002 *	(0.001)
7	-0.005 *	(0.003)	-0.004	(0.003)	0.055 **	(0.023)	0.019	(0.024)	-0.001	(0.001)	0.000	(0.001)
8	-0.004	(0.003)	-0.002	(0.003)	-0.005	(0.023)	0.014	(0.024)	0.001	(0.001)	0.002	(0.001)
9	-0.006 **	(0.003)	0.000	(0.003)	-0.003	(0.024)	0.015	(0.025)	0.000	(0.001)	-0.001	(0.001)
niu	0.003 **	(0.001)	0.001	(0.001)	-0.007	(0.011)	-0.013	(0.011)	-0.001	(0.001)	0.000	(0.000)
mean	0.265		0.463		6.794		5.609		0.050		0.023	
N	654359		536936		518048		351022		664700		549796	

Notes: *significant at 10% level, ** signficant at 5% level, ***significant at 1% level, s.e.'s in parentheses