NBER WORKING PAPER SERIES

THE EFFECTS OF MATERNAL FASTING DURING RAMADAN ON BIRTH AND ADULT OUTCOMES

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Working Paper 14428
http://www.nber.org/papers/w14428

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
October 2008

We gratefully acknowledge comments from seminar participants at the NBER Cohorts meeting Spring 2007, UC Davis, Chicago Harris, the NPC Early Life Events Conference, Brown University, Stockholm University (IIES), the NBER Childrens Program, the University of Illinois (Chicago), the Federal Reserve Bank of San Francisco, Notre Dame, and the University of Chicago (GSB). We also thank Lena Almond, Hoyt Bleakley, Dora Costa, Janet Currie, Carlos Dobkin, Phoebe Ellsworth, Andrew Gelman, Jon Guryan, Jim Heckman, Hilary Hoynes, Emir Kamenica, Darren Lubotsky, Doug Miller, and Diane Whitmore-Schanzenbach for helpful comments. We thank Ana Rocca, Kenley Barrett, Sarena Goodman, and Shyue-Ming Loh for excellent research assistance. The views expressed here do not reflect the views of the Federal Reserve system, nor those of the National Bureau of Economic Research.

The Effects of Maternal Fasting During Ramadan on Birth and Adult Outcomes
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NBER Working Paper No. 14428
October 2008
JEL No. I1,I12,J1,J14

ABSTRACT

We use the Islamic holy month of Ramadan as a natural experiment for evaluating the short and long-term effects of fasting during pregnancy. Using Michigan natality data we show that in utero exposure to Ramadan among Arab births results in lower birthweight and reduced gestation length. Preconception exposure to Ramadan is also associated with fewer male births. Using Census data in Uganda we also find that Muslims who were born nine months after Ramadan are 22 percent (p =0.02) more likely to be disabled as adults. Effects are found for vision, hearing, and especially for mental (or learning) disabilities. This may reflect the persistent effect of disruptions to early fetal development. We find no evidence that negative selection in conceptions during Ramadan accounts for our results. Nevertheless, caution in interpreting these results is warranted until our findings are corroborated in other settings.

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1 Introduction

A growing literature argues that early childhood health exerts a latent impact on outcomes into adulthood. Some of the strongest observational evidence comes from exogenous changes in the health environment outside the control of parents (Currie, 2008). A diverse set of natural experiments in early childhood health provide empirical support, including exposure to famines (Roseboom *et al.* (2001); Chen & Zhou (2007)), the disease environment (Almond, 2006; Bleakley, 2007), and micronutrients (Field *et al.* (2007)).

An unresolved question is whether more mild and commonly-encountered exposures might also exert long-term effects, and therefore how generalizable these latent effects might be. Second, the sensitivity of adult outcomes to childhood health environment may depend critically on the particular stage of childhood considered (Cunha & Heckman, 2007; Heckman, 2007). To shed light on these questions, we would like to evaluate a relatively mild exposure that is nevertheless abrupt or short in duration.

In this paper, we consider changes in the timing of prenatal nutrition due to fasting by pregnant women during the Muslim holy month of Ramadan. The Ramadan fast includes abstaining from eating and drinking beverages during *daylight* hours for a lunar month. A set of biochemical changes known as "accelerated starvation" (Metzger *et al.*, 1982) can occur with extended fasts during pregnancy, but not outside of pregnancy. (Metzger *et al.* (1982) were not studying the Ramadan fast, but rather were interested in the metabolic effects of breakfast skipping in anticipation of laboratory tests.) Whether "accelerated starvation" impacts *fetal* development and birth outcomes has not been established.[1]

As Ramadan follows a lunar calendar, its observance shifts forward 11 days every Julian year. This "drift" together with its month-long duration implies that more than three quarters of pregnancies overlap with Ramadan. Over a period of 32 Julian years, Ramadan completes a full circuit of the western calendar. This feature permits the separate identification of Ramadan from seasonal effects in health (Doblhammer & Vaupel, 2001; Costa & Lahey, 2005; Buckles & Hungerman, 2008). Raman's short duration (29-30 days) allows us to evaluate which *month* of pregnancy is associated with the largest Ramadan effect.

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). In contrast, pregnant women must request a special dispensation from fasting and are generally required to make up the days later when they may be the

[1] Nevertheless, the Institute of Medicine recommends pregnant women should "eat small to moderate sized meals at regular intervals, and eat nutritious snacks" (Institute of Medicine, 1992):45. In a pamphlet on preterm labor for patients, the American College of Obstetricians and Gynecologists recommends that women avoid "skipping meals" (http://www.acog.org/publications/patient_education/bp087.cfm?printerFriendly=yes).

only family member fasting. The majority of pregnant Muslim women (70-90 percent) report that they fasted during Ramadan.[2]

To confirm whether pregnant Muslims indeed appear to observe the fast, our analysis begins with natality data from Michigan – home to a large Muslim population. We observe pregnancy and birth outcomes that potentially could be affected by fasting, such as birthweight, gestation length and the sex of the child. Here, differences in birth outcomes for pregnancies that happen to overlap with Ramadan would suggest that there is indeed a "first stage" in maternal fasting behavior (in the absence of systematic timing of pregnancies *vis à vis* Ramadan, see below). Although we do not know the religion of Michigan mothers, we infer Muslim status based on ancestry.[3]

We find that birthweight is significantly lower among infants of Arab descent who were exposed to fasting during Ramadan *in utero* compared to those whose fetal development did not overlap with Ramadan. The effects are stronger when Ramadan falls during the summer and the diurnal fast is longer. For example, our estimates imply that birthweight would be 50 grams lighter among those whose first month of gestation completely overlapped with Ramadan during the summer solstice. (The effects on those who actually fast are likely to be larger to the extent that not all pregnant Muslim women fast and we include Arabs who are non-Muslim.) We also find significant effects of fasting in reducing gestation length. We find no corresponding effects of Ramadan's timing for non-Arabs.

We also estimate that fasting just prior to conception reduces the fraction of male births by about 6 percentage points. This result is consistent in timing and magnitude with Mathews *et al.* (2008), who used detailed measures of nutritional intake prior to conception (unrelated to Ramadan) and found a large effect on the sex ratio at birth. Mathews *et al.* (2008) speculated that their result could be due to declining glucose levels caused by meal skipping rather than a result of receiving inadequate levels of specific nutrients. Since the sex ratio at birth is often viewed as a proxy for infant health (Mathews & Hamilton, 2005), this result provides further suggestive evidence of a negative effect of fasting on latent infant health.

No previous study has analyzed whether prenatal exposure to Ramadan fasting may affect outcomes in adulthood. To this end, we utilize the 2002 Uganda Census, as it reports both religion and month of birth for a large sample of both Muslims and non-Muslims. This Census also includes a set of disability questions that can be used to assess adult health. We find that the occurrence of Ramadan nine months prior to birth is associated with a 20 percent increase in the likelihood of having a disability in adulthood. Sight, hearing and mental (or learning) disabilities are each significantly elevated.

[2]Women who are in the early stages of pregnancy may observe the fast without knowing their pregnancy status.

[3]Some who report Arab ancestry in Michigan may actually be Chaldeans who are Christian. We check the robustness of our results to excluding zipcodes with large numbers of Chaldeans based on the 2000 Census.

Thus, we conclude that exposure exposure to a relatively mild and short nutritional shock (*cf.* famines) exerts substantial long-term effects.

Our identification strategy assumes that there are no systematic differences among Muslims in the timing of Ramadan relative to fetal development.[4] If, for example, healthier mothers systematically timed conceptions to take place shortly after Ramadan so as to avoid fasting during pregnancy, then this could confound estimates. We assess this possibility by examining whether the number of conceptions appears to vary around the timing of Ramadan. The number of births conceived shortly after Ramadan appears higher, but the increase is slight (roughly 3%, and not statistically significant).[5] More to the point, we find no evidence that mothers observable characteristics — including her educational attainment, receipt of Medicaid (income proxy), or age – vary systematically with exposure to Ramadan during pregnancy in our data. While it suggests that our identification strategy is "clean," the apparent absence of significant pregnancy timing behavior is of interest in its own right: it suggests that either the long-term effects of fasting during pregnancy are unknown, or the cost of shifting pregnancies over time is high relative to the perceived damage.[6]

Although these results are strongly suggestive of a link between daytime fasting and birth and adult outcomes, we suggest caution in interpreting the findings. Our data cannot, for example, show whether 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 conception timing that we have not accounted for. Finally, although our exposition will focus on the meal skipping during Ramadan, there are other behavioral changes coincident with daytime fasting that could conceivably affect fetal health. For example, dehydration from fluid restriction or changes in sleep patterns may also occur during Ramadan and affect fetal health. As is the case with the current medical literature, our approach cannot disentangle these separate effects or their possible interactions. Instead our results may be interpreted as capturing the "reduced form" effect of Ramadan on the outcomes analyzed.

[4]Our empirical approach departs from previous studies that compare birth outcomes of mothers who reported Ramadan fasting during pregnancy with other pregnant Muslims giving birth at the same but who chose not to fast during pregnancy. As the fasting decision may be endogenous to maternal or fetal health, estimates of fasting's effect may be confounded. For example, expectant mothers choosing to fast may have higher pre-pregnancy weights and BMIs than those choosing not to fast (Kavehmanesh & Abolghasemi, 2004).

[5]It is reasonable to expect higher fertility after Ramadan for several reasons. The prohibition of daytime sex ends with the conclusion of Ramadan. In addition, the end of Ramdan is marked by a 3 day celebratory period.

[6]The responsiveness of birth timing to tax incentives found in Dickert-Conlin & Chandra (1999) concerned the timing of deliveries (e.g. through c-sections), not conceptions.

2 Background

We begin by summarizing evidence on the "first stage" effect of fasting during Ramadan. In other words, is there evidence that Ramadan fasting has any measurable effect on human physiology that lends plausibility to the research design? Second, we summarize the biomedical literature on meal skipping during pregnancy, focussing on its impact on maternal biochemical measures and fetal movements. Third, we examine potential pathways by which intermittent fasting could have long-term effects through "fetal programming". Fourth, we review the empirical studies that have explicitly examined the effects of Ramadan on birth and early childhood outcomes. Fifth, we briefly summarize a separate literature on nutrition and the sex ratio at birth (which to date has not used Ramadan fasting for identification). Finally, we distill the above into research hypotheses which we will apply to our data.

2.1 Does Ramadan Have a "First Stage" Effect?

2.1.1 Do Pregnant Muslim Women Fast?

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). This requirement may discourage pregnant women from seeking the exemption since they may 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 to 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 & Yu, 2004).[7]

As far as we are aware, 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 & Nasrollahi, 2001).[8] In a study in Singapore, 87% of the 181 muslim women surveyed fasted at least 1 day during pregnancy, and 74% reported completing at least 20 days of fasting (Joosoph & Yu, 2004). In a study conducted in Sana'a City, Yemen, more than 90 percent fasted over 20 days

[7]Similarly, Arab & 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 *et al.*, 2005).

[8]54% reported fasting 10 days or more. Interestingly, fasting is more common when Ramadan fell in the first trimester (77%) than in the third trimester (65%): table 1.

(Makki, 2002). At the Sorrento Maternity Hospital in Birmingham, England, three quarters of mothers fasted during Ramadan (Eaton & Wharton, 1982). In a study conducted in Gambia, 90 percent of pregnant women fasted throughout Ramadan (Prentice *et al.*, 1983). 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 & Raisler, 2005).

In summary, survey data indicate that most but not all women observe the Ramadan fast during pregnancy. To the extent that pregnant Muslim women do not fast, impact estimates for fasters should be scaled up.

2.1.2 Caloric Intake and Weight

Studies of Ramadan fasting in the general population have often found modest but statistically significant declines in the weight of fasters of around 1 to 3 kg (Husain *et al.* (1987); Ramadan *et al.* (1999); Adlouni *et al.* (1998); Mansi (2007); Takruri (1989)) Reductions in weight are sometimes (but not always) accompanied by declines in caloric intake and likely depend on dietary customs in specific countries.[9]

Two studies are of particular relevance for our purposes. First, in a study of 185 pregnant women, Arab (2003) found that over a 24 hour period encompassing the Ramadan fast, over 90 percent of the women had a deficiency of over 500 calories relative to the required energy intake and 68 percent had a deficiency of over 1000 calories. Second, in the only large scale population-based study we are aware of, Cole (1993) found striking evidence of sharp weight changes during Ramadan for women in Gambia. The study was notable because it used fixed effects with 11 years of panel data and controlled for calendar month, calendar year and stage of pregnancy (or lactation). Figure 1, taken from the study, shows that relative to the rest of the year, there is an increase in weight during the four weeks prior to Ramadan and a sharp increase in weight at the very beginning of Ramadan. This is followed by an abrupt fall in weight of over 1kg (2.2 pounds) during the subsequent 3 weeks of fasting. The figure provides striking visual evidence that daytime fasting during Ramadan is affecting weight gain.

In any case, as we will discuss in sections 2.2.1 and 2.3, fasting may induce maternal biochemical changes and reprogramming of the neuro-endocrine system due to alterations in the the *timing* of nutritional intake even if overall caloric intake or weight change was unaffected.

[9]For example, Husain *et al.* (1987) found reductions in caloric intake of between 6 percent and 25 percent relative to nonfasting conditions among Malaysians. In contrast, Adlouni *et al.* (1998) found a 20 percent increase in calories per day among Moroccans.

2.2 Ramadan and Prenatal Health

2.2.1 Maternal Biochemical Response

Writing in *The Lancet,* Metzger *et al.* (1982) documented a set of divergent biochemical measures among 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 and alanine was lower in the pregnant women than non-pregnant women after 12 hours of fasting while levels of free fatty acids and beta-hydroxybutyrate, a ketone, were significantly higher.[10] "Accelerated starvation" in pregnancy[11] occurred after only "minor dietary deprivation" for both lean and obese women. Metzger *et al.* (1982) concluded that meal-skipping "should be avoided during normal pregnancy." Accelerated starvation has specifically been linked to fasting by pregnant women during Ramadan in Gambia (Prentice *et al.*, 1983) and England Malhotra *et al.* (1989). Malhotra *et al.* (1989) conclude it is "prudent to recommend that mothers take up the dispensation offered to them during Ramadan." Mirghani *et al.* (2004) found that the number of consecutive days fasted appeared to have an independent effect, suggesting "the effect on maternal glucose levels during Ramadan fasting is cumulative."

A key concern related to accelerated starvation is whether fetal exposure to "ketones" could potentially impair the intellectual development of the fetus. Experimental studies in mice and rats have shown that prenatal exposure to ketones early in gestation results in impaired neurological development (Hunter & Sadler, 1987; Moore *et al.*, 1989; Sheehan *et al.*, 1985).[12]

A separate literature has examined the implications of hypocglycemia during pregnancy among mothers with Type 1 diabetes.[13] Some studies have shown that fetal growth is reduced and that the key period is between the

[10] It is also notable that Meis & Swain (1984) found that daytime fasts result in significantly lower glucose concentrations than nighttime fasts.

[11] First documented by Freinkel among diabetic women during pregnancy (Freinkel *et al.*, 1972).

[12] Hunter & Sadler (1987) suggest that in addition to the period of neurulation (3rd to 4th week of gestation in humans), the earliest stages of embryogenesis when the "primitive streak" is observed (the 13th day post-conception), may be especially susceptible to ketones. Moore *et al.* (1989) noted that "even a relatively brief episode of ketosis might perturb the development of the early embryo":248. They also emphasize that the effects of ketones were to slow neurological development rather than to produce a malformation. This may explain why similar studies in human populations have not (for the most part) found evidence of congenital malformations (ter Braak *et al.*, 2002) On the other hand studies among diabetic mothers have shown long-term effects of *in-utero* exposure to hypogycemia on cognitive functioning during childhood (Rizzo *et al.*, 1991; Langan *et al.*, 1991). Interestingly, Rizzo only found effects on intelligence scores for those exposed during the first trimester.

[13] Although the primary concern is the avoidance of hyperglycemia (abnormally high blood glucose), this sometimes results in severe cases of hypocglycemia (abnormally low blood glucose).

fourth to sixth weeks of gestation (ter Braak *et al.*, 2002). It has also been shown that hypoglycemia among *non-diabetic* mothers is also associated with lower birth weight (Scholl *et al.*, 2001).

2.2.2 Fetal Health

Studies of hypoglycemia in animals and humans have examined the fetal heart rate, fetal breathing movements and limb and body movements in order to identify impairments to fetal development. A review of these studies in ter Braak *et al.* (2002) do not show much affect of moderate hypoglycemia on fetal conditions.

In contrast, several studies of maternal fasting during Ramadan have found adverse effects on at least two of these indicators. Mirghani *et al.* (2004) found evidence of reduced fetal breathing movements where measures of fetal breathing were taken both before and after fasting on the same day. The same study, however, found no change in overall body movements, fetal tone or maternal appreciation.[14] Mirghani *et al.* (2005) found a significantly fewer heart rate accelerations among pregnant women who were fasting during Ramadan late in pregnancy compared to an identical number of controls. This was observed despite relatively short diurnal fasts (less than 10 hours duration) and the absence of significant changes in glucose levels. A recent study by DiPietro *et al.* (2007) finds a strong association between variation in fetal heart rate *in utero* and mental and psychomotor development and language ability during early childhood. Finally, Mirghani *et al.* (2007) found no effect of Ramadan fasting on uterine arterial blood flow.

2.3 Mechanisms of Fetal Programming

In a review of epidemiological studies on the fetal origins of adult diseases, Jaddoe & Witteman (2006) describe two hypotheses that are of relevance to this study. The first is described as "fetal undernutrition." According to this view, inadequate prenatal nutrition leads to developmental adaptations that are beneficial for short-term survival but lead to lower birth weight. However, by permanently reprogramming the physiology and metabolism of the fetus, this ultimately makes the body susceptible to heart disease and diabetes during adulthood.[15] Although most studies of fetal origins have relied on blunt measures such as birth weight to proxy for nutritional restriction during pregnancy, a recurring theme in many studies is that fetal programming may occur even in the absence of birth weight effects.[16]

[14] A significant reduction in upper limb movements was noted but there was a concern that this might be due to observer bias.

[15] Jaddoe & Witteman (2006) note that this view has evolved into a more "general developmental plasticity model in which various fetal and post-natal environmental factors lead to programming responses":93.

[16] For example, studies of the Dutch famine have showed that those exposed to the famine early in gestation had dramatically higher rates of heart disease but did not have lower

A second prominent hypothesis is that nutritional restrictions inhibit the development of a placental enzyme that is required to convert cortisol into inactive cortisone, thereby exposing the fetus to excessive amounts of cortisol. It is suggested that exposure to glucocorticoids such as cortisol *in utero* leads to a reprogramming of the hypothalamic–pituitary adrenal axis (HPA) which in turn, could lead to impaired fetal development and worse health during adulthood. In carefully controlled animal studies, researchers have linked nutritional restrictions very early in gestation to an altered neuro-endocrine system (e.g. (Nishina *et al.*, 2004)). With respect to humans, (Herrmann *et al.*, 2001) have shown an association between fasts of 13 hours or greater and higher levels of plasma corticotrophin-releasing hormone (CRH) which could reflect a reprogramming of the HPA axis. Kapoor *et al.* (2006) describe how the 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". The authors also emphasize that many of the long-term effects may be sex-specific.

The existing literature on fetal origins however, has made little use of quasi-experimental research designs to address potential confounding factors or to identify the underlying mechanisms. Jaddoe & Witteman (2006) write: "Thus far, it is still not known which mechanisms underlie the associations between low birth weight and diseases in adult life. The causal pathways linking low birth weight to diseases in later life seem to be complex and may include combined environmental and genetic mechanisms in various periods of life. Well-designed epidemiological studies are necessary to estimate the population effect size and to identify the underlying mechanisms":91.

2.4 Ramadan and Perinatal Health

2.4.1 Birth Outcomes

The medical literature to this point has found mixed evidence with respect to birth outcomes such as birthweight with most studies finding no statistically significant effects. However, the sample sizes in most medical studies tend to be small and they typically focus on mid to late gestation. More importantly, they rely on comparing fasters to non-fasters at a point in time and have sometimes have used questionable control groups. None of the studies use a large set of birth cohorts for whom Ramadan occurred in many different months to compare Muslims exposed to Ramadan fasting *in utero* to those with no prenatal exposure. We are also unaware of any previous study that takes advantage of the number of daylight hours during the Ramadan fast for identification.

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birth weight (Painter *et al.*, 2005). Similarly animal studies have often found evidence of fetal programming without detecting significant changes in fetal weight. e.g. Nishina *et al.* (2004)

Kavehmanesh & Abolghasemi (2004) compared 284 births to mothers in Tehran with a "history of fasting during pregnancy" to 255 mothers who did not fast. Although there were no statistically significant differences with respect to maternal education or height, pre-pregnancy BMI's were substantially higher in the fasting group raising concerns about the design of the study. Shahgheibi *et al.* (2005) studied 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 statistically significant with the small sample used, the authors concluded that fasting during the third trimester had "no effect" on growth indices. Arab & Nasrollahi (2001) studied 4,343 pregnancies in the Hamdan province of Iran and concluded that fasting did not impact birth weight. They did note however, that the incidence of *low birth weight* (< 2500 grams) 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 *et al.* (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 but instead compared across groups of Muslims and Non-Muslims. 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 & Nasrollahi (2001), Cross *et al.* (1990) also found a higher incidence of low birth weight among fasters during the second trimester. Finally, Opaneye *et al.* (1990) found 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 these studies find no effect on birthweight, it is worth noting that both Malhotra *et al.* (1989) and Mirghani & 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.

A separate literature has found that skipping meals (*not* associated with Ramadan) has been associated with preterm delivery. Siega-Riz *et al.* (2001) studied diets during the second trimester of pregnancy for over 2000 women in North Carolina and found that women who did not follow the optimal guidelines of three meals and two snacks a day were 30 percent more likely to deliver preterm. They suggest that this is consistent with experimental evidence from animal studies. Herrmann *et al.* (2001) also reported that women who fasted for 13 hours or more were three times more likely to deliver preterm.

With respect to other birth outcomes, Mirghani & 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, cesarian sections, and admission to the special baby care unit.

2.4.2 Longer-term Effects?

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 in this respect 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.[17] 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.

2.5 Nutrition and the Sex Ratio at Birth

A well known evolutionary theory, the Trivers-Willard hypothesis (1973) suggests that the reproductive success of sons is more sensitive to maternal condition than that of girls. Therefore, parents experiencing better conditions may favor male offspring. More generally, the sex ratio at birth may also be viewed as a proxy for latent infant health (Mathews & Hamilton, 2005). 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. A recent study by Mathews *et al.* (2008) has for the first time drawn a link between maternal nutrition prior to conception and the sex ratio at birth. The authors collected detailed information on food intake prior to pregnancy, early in pregnancy (14 weeks gestation) and late in pregnancy (28 weeks gestation). They found no differences in the rates of male births arising from differences in nutritional intake either early or late in pregnancy but found a highly statistically significant positive relationship between high nutritional scores prior to conception and the birth of male offspring. They further examined the detailed data on sources of nutrition and found that among 133 food items consumed prior to pregnancy, only breakfast cereals was strongly associated with infant sex.

The authors speculate that the mechanism underlying this connection is that the skipping of breakfast "extends the normal period of nocturnal fasting, depresses circulating glucose levels and may be interpreted by the body as indicative of poor environmental conditions." They also cite research from

[17] 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).

Larson *et al.* (2001) that studies *in vitro* fertilization of bovine embryos and shows that glucose "enhances the growth and development of male conceptuses while inhibiting that of females."

The study by Mathews *et al.* (2008) was observational and did not explore the source of dietary differences across mothers, and whether these were associated with other factors known to influence the sex ratio (e.g., partnership status at the time of conception (Norberg, 2004) or maternal age, education, and marital status at the time of birth (Almond & Edlund, 2007)). Short of a controlled experiment, the research design utilized here has the advantage of leveraging plausibly exogenous differences in fasting behavior.

2.6 Hypotheses: Outcomes and Timing

In this section we organize evidence from some of the existing literature to inform the hypotheses that we will explore in the remainder of the paper. In Table 1 we summarize the set of outcomes for which we might expect to see effects due to fasting, a brief description of the mechanism by which the outcome is affected, and the period of exposure during gestation that has been suggested, or found to be critical. These hypotheses are based on either a clearly defined pathway linking fasting to a particular outcome, or an empirical result that has been established in a prior study, irrespective of whether there is an explicit mechanism described in the study. It should be noted that in many of the studies, the period of *in utero* exposure was selected by design and therefore the fact that an effect was found in the chosen gestation period does not rule out possible effects in other periods.

For example, for birthweight we describe four mechanisms by which birth weight might be affected and one empirical finding based on the Dutch famine. Two of the channels for birthweight are tightly linked to very early exposure. For several outcomes there are no clear hypotheses concerning timing that we could discern and so a reasonable hypothesis would be to jointly test the effects of Ramadan exposure during all gestation months.

With respect to longer-term outcomes, in virtually all cases early exposure to fasting is the predominant hypothesis. It is also worth noting that there are several arguably distinct channels by which cognitive impairments may be affected by fasting.

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 totalling approximately 2.3 million records. The natality data identifies the self-reported 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. Michigan is especially useful for this analysis because of its large Arab population, the majority of whom are likely to be Muslim. There are a total of about 50,000 births to mothers of Arab ancestry or about 2.2 percent of all births over this period. While there is a large population of Arabs around Detroit, the Arabs population is also reasonably dispersed around the state (Figure 2, Panel A).

Data is collected on several birth outcomes including birthweight, gestation length, Apgar scores, type of delivery (e.g. C-section), transfer to a neonatal intensive care unit (NICU). There is also detailed data on pregnancy complications, abnormal conditions and congenital anomalies. There is a fairly rich set of demographic variables including mother's and father's age, race and education as well as zipcode of residence. There is also information on the mother's behavior during pregnancy including smoking, drinking, maternal weight gain and use of prenatal care.

There are at least two limitations to the use of reported ancestry in the natality data. First, according to the 2000 Census about a quarter of those of an Arabic speaking ancestry in Michigan are Chaldean Christians, who presumably do not observe the Ramadan fast. According to the Detroit Arab American Study (DAAS), which surveyed just over 1000 Arab Americans and Chaldeans in the Detroit metropolitan area, 58 percent identified themselves as Christian and only 42 percent as Muslim. The study further reveals that 63 percent of the Chaldeans identified themselves as "Arab American".[18] Therefore, any effects of Ramadan fasting on Muslim births based on using self-reported Arab ancestry as a proxy for Muslim status are likely to be attenuated. In order address this we utilize Census data on ancestry by zipcode to identify areas of heavy concentrations of Chaldeans relative to Arabs (Figure 2, panel B). We test the robustness of our results to dropping observations from these zipcodes. A second concern is that there may be a significant degree of under-reporting of Arab status.[19] This suggests that some births that we assign non-Arab status may in fact be of Arabic origin and could contaminate any results that utilize non-Arabs as an additional control group, or as a validity check. We address this by also presenting results for non-Arabs who, according to the Census, live in zipcodes with little or no Arab presence. We also implement several other sample selection rules to minimize measurement error and misclassification of Muslim status.[20] Our main sam-

[18] Author's calculations based on the DAAS microdata.

[19] According to the 2000 Census there were about 150,000 individuals of Arabic speaking ancestry living in Michigan. This implies that only about 1.5 percent of the population is Arabic. However, according to the Arab American Institute, there are closer to 500,000 Arabs living in Michigan which would imply that nearly 5 percent of the population is Arabic.

[20] 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 blacks to avoid the possibility that there might be "Black Muslims" in our sample. We also dropped twin births and restricted the sample to births among mothers between the ages of 14 and 45.

ple includes about 40,000 Arab births and 1.5 million non-Arab births. The summary statistics are shown in Table 2.

The key variables for identifying *in utero* Ramadan exposure are birth date and gestation length. The data provides the exact date of birth and also provides a self-reported date of last menstrual period (LMP) for about 70 percent of the sample. The problem of selective reporting of LMP based on socioeconomic status is well known (Hediger *et al.*, 1999). There is also a variable containing the physician estimated gestation length, but we do not know how it is calculated and when during gestation it is calculated.[21] To address these issues, we follow some related studies (e.g. Siega-Riz *et al.* (2001), Herrmann *et al.* (2001)) that utilize a simple algorithm for measuring gestation. Gestation based on LMP is used except if it is missing or if it differs with physician estimated gestation by more than 14 days, in which case the physician estimated measure is substituted. We also present estimates that ignore the gestation measures and simply calculate Ramadan exposure assuming normal gestation length.

3.2 Uganda Census 2002

The second part 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. At the time this project began, Uganda was the only country in the IPUMS-I with a very large muslim population for which information on both month of birth and religion were collected.[22] The Uganda sample is a 10% sample of the population and the entire sample contains about 2.5 million 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.[23] 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?

[21] A key concern is that this could be endogenous to Ramadan exposure. For example, if Ramadan affects fetal size and if physician estimates of LMP are based on measures of fetal size, this could lead to mis-measurement of the timing of Ramadan exposure. In addition, this measure might not be calculated uniformly and may depend on the timing of the first doctor visit and could therefore, be correlated with mother's socioeconomic status.

[22] Birth month and religion are available in the census of South Africa (unharmonized variables in IPUMS-I), but the share of Muslims is extremely small. In the US, the month of birth is generally not reported in the Decennial Census; the National Health Interview Survey does not disclose religion, detailed ethnicity, or country of birth.

[23] 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.

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 disabilities.[24] 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.

The summary sample statistics are described in Table 3. 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. Figure 3 shows that Muslims are more heavily concentrated in the southeastern portion of the country.

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 4 we have 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 occurrence during gestation. Therefore, we exclude those individuals whose reported age ends in zero.

3.3 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.[25] We then constructed measures of *in utero* Ramadan exposure utilizing information either on the exact birth date or the birth month. For Michigan, where we have the exact birth date, we assembled several measures of Ramadan exposure tied to every single day over the 1989 to 2005 period. The first measure (*exphrspct*) utilizes the number of daylight hours in each day. This allows us to distinguish periods of especially prolonged fasting when accelerated starvation is more likely, from shorter fasting periods.[26] Specifically, the numerator of this measure is the number of daylight hours over the next 30 days that overlap with Ramadan and the denominator is the maximum number of daylight hours over any 30 day period over the entire sample period.

[24]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".

[25]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.

[26]The daylight hours are measured for the city of Dearborn which contains a large share of the state's Arab population.

Daylight hours in Michigan vary from a low of around 9 to a high of 15. Our second measure (*exppct*), calculates the number of days over the subsequent 30 days that overlap with Ramadan.

A third measure (*rampct*) which is useful when we only know the birth month, as in our Uganda sample, is only calculated for each month. This measure is the fraction of days in each month that overlap with Ramadan. We opted to use this measure, rather than a simple dummy variable since it provides a continuous measure of treatment (more power). Since Uganda is at the equator, the number of daylight hours is fairly constant over the year at 12.

With our Michigan sample we use three different approaches for assigning *in-utero* Ramadan exposure because of our concerns about the quality of data on gestation (see 3.1). The first approach uses the exact date of birth and simply assumes that all births have a normal gestation length of 40 weeks. The Ramadan exposure measures are assigned by going backwards from the birth date in 30 day increments and using *daily* exposure measures (*exphrspct* and *exppct*) from 30 days prior to birth to 270 days prior to birth. Using this approach the measure of Ramadan exposure 9 months prior to birth is a proxy for the actual exposure during the "first month" of gestation. Our second approach incorporates the measures of gestation in the data to match each individual to an estimated date of conception.[27] We then assign Ramadan exposure for the first month based on the daily exposure measures for the date that is 4 days prior to the estimated date of conception.[28] We then proceed to assign Ramadan exposure measures forward in 30 day increments. Using this approach a child born after say, 34-35 weeks of gestation would only have been *in utero* for about 8 months and therefore only the first 8 exposure variables are actually relevant. Our third approach ignores information on exact birth date and actual gestation. This 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.

Figure 5 provides a hypothetical example to illustrate how our daily measures of Ramadan exposure are calculated. In 1989 Ramadan began on April 7th and ended on May 6th. For someone who was conceived on April 6th, his or her entire first month of gestation would overlap with Ramadan, i.e. *exppct*=1. Since during this Ramadan, daylight hours averaged about 13.7 hours per day, compared to 15.2 during the summer solstice, the hours exposure measure (exphrspct) peaks at about 0.9. Someone conceived on March 21st or April 21st would have only half the amount of Ramadan exposure during the first month of gestation. It is also worth noting that someone conceived

[27]Gestation is measured as starting from the date of last menstrual period (LMP) and the conception date is estimated as occurring 14 days after LMP.

[28]This ensures that we have lined up the gestation month exposure in a parallel way to that used in the first approach. In other words, if a birth has exactly 40 weeks or 280 days of gestation, using either approach we will start measuring gestation exactly 270 days prior to birth.

on April 21st (during Ramadan) would also have about 15 days of exposure to fasting during the *pre-conception* period.

3.4 Econometric Model

Our main approach is to regress each outcome, y, on our measures of Ramadan exposure (*exphrspct*, *exppct* or *rampct*) during each month of gestation. This allows us to test the hypotheses laid out in section 2.6. All gestation month exposure measures are included simultaneously in each regression even though an individual will only be exposed to Ramadan in at most two different months of gestation. The effects on Ramadan exposure in a given month of gestation, therefore, are measured relative to having no exposure to Ramadan *in utero*. Additional controls include birth year dummies, a set of calendar birth month dummies (or conception month dummies if gestation data is used) and a set of dummies that measure geographic location at the time of birth.[29] 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 in Uganda we include a female dummy.

$$y_{iymg} = \alpha + fem + year_y + month_m + geog_g + exphrspct_1 + exphrspct_2 + ...exphrspct_9 + \varepsilon_i \quad (1)$$

In a typical specification where we include nine months of exposure simultaneously, we also run an F-test on the joint significance of all nine coefficients. This tests the overall effect of Ramadan exposure during any point in gestation. In addition, since our hypotheses for some outcomes suggest an effect only in specific gestation months, we also run tests of equality of all coefficients.

Our primary specification and our estimates are based on using a Muslim sample. However, when we use a Non-Muslim sample as a validity check, the birth timing and birth location effects are allowed to vary across groups. For some estimates (e.g. sex ratio) we use aggregate measures at the cell level where cells are defined by each of the distinct conception or birth month over the sample period.

4 Michigan Results

4.1 Birthweight and Gestation

Table 4 presents the results on birthweight. In the first four columns we utilize the approach of linking births to *in utero* Ramadan exposure by assuming everyone has the normal gestation length. This is useful because it allows us to avoid having to use a select subsample of births where gestation is self-reported. It also allows us to see the effects of moving from using daily

[29] 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.

exposure measures to monthly exposure measures as we are forced to do in the Uganda sample. The first column labels the coefficients on Ramadan exposure by the number of months prior to birth starting with 10 months prior to birth all the way to the month of birth.

The next two columns uses the daylight hours based measure of Ramadan exposure (*exphrspct*). The most striking result is found in the first entry of column 1 which suggests that birthweight would be lower by 51 grams if an Arab mother was in the first month of pregnancy (i.e. nine months before birth) during the summer solstice and Ramadan took place at this time. This result is significant at the 1 percent level. In addition, the other entries in column 1 imply that gestation months 2, 4 and 6 also show effects of around 40 to 50 grams and are significant at the 5 percent level. We also find that the F-test on the joint importance of all the Ramadan exposure measures is significant at the 2 percent level. The test of the equality of coefficients is rejected at the 6 percent level.

As a robustness check we also include Ramadan exposure 10 months prior to birth in column 2. Since no study that we are aware of suggests that fasting prior to conception should affect birthweight, we should not see any effect. Column 3 shows no effect for the month prior to conception and the inclusion has little effect on the results. In column 4 we address the concern that the effects of fasting may be diluted due to the inclusion of Chaldeans, who are not Muslim but might self identify as Arab. Specifically we drop mothers whose zipcode of residence has a majority of Chaldeans among its Arab population according to the 2000 Census. This drops our sample by nearly 28 percent and raises the standard errors. Nevertheless, we continue to find significant effects particularly in the first two months of gestation. The F-test of joint significance continues to reject the hypothesis that there is no effect from Ramadan exposure.

In column 5 we measure Ramadan exposure by the fraction of days in the gestation month that overlap with Ramadan. This removes any variation in Ramadan exposure arising from the number of daylight hours. It also changes the interpretation of the coefficient to reflect the average effect of Ramadan exposure across all seasons. Unsurprisingly, this reduces the effect size to about 30-35 grams but the effects are also highly significant, especially during the first month which is still significant at the 1 percent level. We now find that all nine coefficients are jointly significant at the 1 percent level and that we can reject the equality of the nine coefficients at the five percent level. The sixth column ignores information about the exact date of birth and only utilizes the birth month to calculate exposure measures of the fraction of days in each month that overlap with Ramadan. With this approach we now find only the second month and the seventh of gestation to be significant and that the coefficients are no longer jointly significant or significantly different from one another. Nevertheless, the effect size remains in the 30 to 40 gram range. Using only birth month appears to smooth the effects across adjacent months based on the daily exposure measure.[30]

In the remaining columns of Table 4 we utilize the gestation data and use all births that were between 37 and 42 weeks of gestation to produce a comparable set of results. This ensures that at least the first 8 exposure measures are reasonably interpretable since all of these births would have been *in utero* for 8 months. It also provides a large enough sample of Arabs to provide reasonably precise estimates. The drawback to using this cutoff is that it does not include preterm births (< 37 weeks) where we have hypothesized that fasting might play an important role. We examine birthweight effects in pregnancies of shorter gestation in a subsequent table.

In the first two specifications that utilize the daylight hours index of exposure, we find effects that are statistically significant at the 5 percent level for exposure in months 1 and 6. The size of these effects are between 35 and 45 grams. We also find two months (5, 7) that are significant at the 10 percent level. With this sample, which is about 7 percent smaller than the previous samples that ignore gestation length, we cannot reject that there is no effect or that the effect is constant across gestation. This suggests that part of the difference from the results in the previous columns may be due to selection on nearly full-term births.

In the last column where we drop heavily Chaldean zipcodes we now find more uniformly strong effects of about 40 to 45 grams. Six of the gestation months (1, 2, 5, 6, 7 and 9) are now significant at at least the 10 percent level and the joint test on the coefficients rejects that there is no effect from Ramadan exposure at the 9 percent level. Overall, it appears that a reasonable summary of these results is that: i.) *in utero* exposure to Ramadan is associated with lower birthweight; ii.) a full month of exposure to Ramadan during the summer solstice could lead to as much as a 50 gram reduction in birthweight and iii.) these effects appear to be consistently large during the first month of gestation. The size of this effect is relatively small as 50 grams is only about 1.5 percent of the mean birthweight for Arabs. Nevertheless, it is still about a quarter of the 200 gram gap in birthweight commonly attributed to smoking and more than third of the black-white gap[31]. Furthermore, these effects are population averages and do not account for the fact that some fraction of these women are not actually fasting. If for example, one-third of women do not fast then the birthweight effects should be inflated by 50 percent.

In Table 5, we vary the samples used to estimate birthweight effects based on the length of gestation. In column 1 we start with a sample of all births with gestation length 25 weeks to 42 weeks allowing us to include preterm births. The coefficients for months 1 to 5 are shaded to indicate that these are the only coefficients that are interpretable for all sample members.[32] We

[30]For example, the effect for month 2 of gestation (8 months before birth) appears to combine a portion of the effects arising from the first two months.

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

[32]For example, exposure in months 6 to 9 will include the effects of Ramadan exposure

then progressively tighten the sample restriction by increasing the lower bound on gestation age producing samples of length 27-42 weeks, 31-42 weeks, 35-42 weeks and 39-42 weeks. This incrementally increases the number of exposure month coefficients that can be interpreted. Interestingly, this does not appear to have any pronounced effects on the results. With the larger samples that include preterm births, exposure during the fifth and sixth months are statistically significant at the 5 percent level. In addition, with the first four samples we can conclude that the coefficients are jointly different from zero with significance levels ranging from 3 percent to 6 percent.

In Table 6 we directly estimate the effects of in-utero Ramadan exposure on gestation weeks using the same approach. Among those with 25-42 weeks gestation, we estimate that Ramadan exposure during the fifth month of pregnancy reduces gestational age by 0.15 weeks or by roughly a day ($p < 0.05$). However, this is the only month where exposure is statistically significant and we cannot reject that the first five gestation months jointly, have no effect. The effect from month 5 exposure weakens a bit as the sample is gradually restricted but remains significant in nearly all specifications. Interestingly, the final column shows that when the sample is confined to only full term births, four gestation months (2, 3, 5 and 8) are significant at the 10 percent level. In order to identify the birthweight effect that arises from decreased gestational age we ran a separate regression of birthweight on gestation for the sample of non-Arabs and found that each additional week of gestation adds about 165 grams. This suggests that a reduction in gestation of 0.15 weeks (our largest estimated effect) implies a 25 gram reduction in birthweight. So at most, half of the overall reduction in birthweight that we estimate in Tables 4 and 5 is due to reduced gestation as opposed intrauterine growth restriction (IUGR). For those exposed early in pregnancy, it appears that virtually all of the birthweight reduction is due to IUGR.

As a check on the validity of the overall birthweight results we apply the same approach to our non-Arab sample. We present these results in Table 7. The first set of columns use the approach of assuming normal gestation for the whole sample, while the second set of columns utilize the gestation data and present the results for the sample of full-term births. Within each of these sets of results, we use either all non-Arab mothers or non-Arabs mothers living in non-Arab zipcodes (according to the Census).[33] The latter samples are smaller but are much more likely to remove any Muslim Arabs that might fail to accurately report their ancestry. We find no birthweight effects that are comparable to the results in Tables 4 and 5. Using the full sample of non-Arabs we obtain small negative coefficients none of which are significantly different from zero at the 5 percent level. The p-values on the joint test of all 9 coefficients are never close to significant. When we exclude Arab zipcodes,

in the postnatal period for the small subsample of those with only 25 weeks gestation.

[33]The results are unaffected if we use the natality data to identify non-Arab zipcodes. However, given that we have more confidence in the reporting of ancestry detail in the Census we opted to use those figures.

the coefficients tend to be more positive but not significantly different from zero.

Finally, in Figure 6 we show which parts of the birthweight distribution are affected by early exposure to Ramadan fasting. We plot kernal densities comparing the birthweight distribution of those Arabs with no *in utero* exposure to those who had a significant exposure to Ramadan in the first month of gestation (*exphrspct1* > 0.5).[34] Most of the effect is in the middle part of the distribution. Specifically, those with first month exposure to Ramadan are more likely to have birthweight between 2800 and 3200 grams and less likely to have birthweight between 3250 and 3900 grams.[35] This suggests that little of the effect is at the low end of the distribution among those classified as "low birthweight" (<2500 grams).

4.2 Sex Ratio at Birth

We next examine the effects of fasting on the fraction male and the sex ratio at birth. As discussed in section 2.5, the key hypothesis based on Mathews *et al.* (2008) is that fasting prior to conception rather than during the *in utero* period will skew the sex ratio in favor of girls. To test this we produced aggregate counts of male and female births to Arab mothers for all calendar months based on the month of *conception.* This results in a little more than 200 observations spanning the the period from March 1988 to June 2005.[36] The mean fraction of births (weighted) that are male is 51.7 percent for Arabs over this period and the mean ratio of male births to female births was 1.08. The comparable figures for non-Arabs are 51.3 and 1.05. In these specifications we either regressed the ratio of male to female births or the fraction of male births, on the *exphrspct* measures of Ramadan exposure over a period surrounding the time of conception.[37] We did this using both the full sample of Arab mothers and the more restricted sample of Arab mothers that excludes zipcodes with a heavy Chaldean presence.

Table 8 presents the results. To be consistent with our earlier tables we show the effects by gestation month. Therefore, gestation month 1 is the

[34]We also ran linear probability regressions using indicator variables of being in specific intervals of the birthweight distribution (e.g. 300-600 grams, 600-900 grams etc.) as an outcome including our other controls and obtained very similar results.

[35]There are also small differences between the samples in the interval from 2100 grams to 2700 grams, and for birthweight greater than 4500 grams.

[36]We have no observations conceived in December 1987. We have also dropped any months with missing female or male births.

[37]Regressions are weighted using the counts of individuals in each cell. We present the period two months prior to conception and out to five months after conception. The effects are therefore measured relative to Ramadan occurring three months prior to conception or during the last trimester of pregnancy (for full-term births). Since fetal deaths are rare after five months of pregnancy we viewed this as a suitable control group. Including the last trimester has almost no effect on the estimates but reduces the precision of the estimates.

month of conception and gestation month "0" is the month prior to conception. In the first column of results, using the full sample of Arabs, we show that Ramadan exposure in the month just prior to conception results in a sharp reduction in the ratio of male to female births by 0.2 (p-value $< .05$) or about an 18 percent effect evaluated at the mean. No other month is significant. In the next column, we estimate that the share of male births would fall by 4.4. percentage points. This implies a reduction from 5.7 percent to 47.3 percent. In the third column of results, using the more restricted sample that excludes Chaldean zipcodes, we find an even larger effect of -0.27 on the sex ratio for births conceived just after Ramadan or about a 25 percent effect. In the next specification, we show that the effect on the male share is -6.0 percentage points for this sample. Turning to the last two columns, we find precisely estimated effects that are close to zero when we use the full sample of non-Arabs. In particular we see no effect among non-Arabs in the month prior to conception. Figure 10 depicts the effect of Ramadan on the sex ratio graphically showing that those conceived during Ramadan –most of whom will have experienced fasting prior to conception– are less likely to be male.[38]

In contrast to women who are already pregnant, fasting rates among women who have not yet conceived are likely to be extremely high. This might explain the sizable effects on the sex ratio at birth. In our other birth outcomes, gestation month effects are likely to represent a combination of the fasting rate at the time of gestation and the effect of fasting on the outcome conditional on fasting.

4.3 Other Birth Outcomes

There are several other birth outcomes that we examine in Table 9. These include low birth weight (birth weight < 2500 grams), the 5 minute APGAR score, maternal weight gain, transfer to a neonatal intensive care unit, C-section, pregnancy complications, abnormal conditions and congenital anomalies. We find only two effects that are statistically significant at the 5 percent level. Exposure during the sixth month of gestation is associated with a higher rate of C-sections and month 9 exposure is linked to a greater likelihood of an abnormal condition. We also find a higher incidence of low birth weight from month 6 exposure that is only significant at the 10 percent level. This may be of some note since some previous studies have also found a second trimester effect on low birth weight.

We also experimented with the sample that excludes zipcodes with a large share of Chaldeans (not shown) and found no effect on C-sections but a similarly sized effect on abnormal conditions arising from exposure in month 9. With this more restricted sample we also identified statistically significant effects on the apgar score from Ramadan exposure in months 6 and 9. However,

[38]This figure uses a simple regression adjustment described in section 4.4 that does not incorporate our day time hours exposure measure.

given the absence of any clear basis for these particular effects and their lack of robustness to sample choice, we do not emphasize these results.

4.4 Selective Timing of Conceptions Around Ramadan, Michigan

A key assumption of the identification strategy is that the composition of Muslim parents does not change systematically by their children's *in utero* exposure to Ramadan. One might be concerned for example, if individuals of higher socioeconomic status (SES) seek to avoid having pregnancies overlap with Ramadan by timing conceptions during the two or three months just after Ramadan. We might also be more generally concerned that fertility patterns change abruptly around Ramadan in such a way as to produce some of the observed results. For example, the end of Ramadan (*Eid ul-Fitr*) is a major event for Muslims and is celebrated with a three day period of festivities. It would not be entirely surprising if after a month of restriction on sex during daytime hours and the end of a period of piety, there was a higher rate of conceptions. If fertility among *high SES families in particular*, was higher for some reason after Ramadan this could conceivably provide an alternative explanation besides fasting for the general pattern of lower birthweight among those exposed at anytime *in-utero*. It is important to note that this would not explain the differences in exposure effects *within* the gestation period. For example, in order to explain the negative birthweight effects on first month exposure to Ramadan as an artifact of unobserved factors, it would have to be the case that these unobserved factors affected conceptions in the month prior to Ramadan.

We address these concerns by presenting a series of charts that show how conceptions and key socio-economic characteristics of the women who conceive, changes around Ramadan.[39] We do this both for Arab and non-Arab mothers and plot regression adjusted means that identify patterns for the seven months that surround Ramadan relative to the baseline period.[40] Figure 7 shows that the mean level of mother's education relative to the baseline months is essentially flat for both groups for conceptions around Ramadan. If anything, mean education is slightly higher among mothers who conceive prior to Ramadan and slightly lower for mothers who conceive in the two months after Ramadan although none of these differences are statistically or qualitatively meaning-

[39]We have also run our outcome models using our measures of mother's SES as outcomes and found no statisitically significant effects. These results are available upon request.

[40]We first aggregate the data (excluding Chaldean zipcodes) to produce time series of population counts and mean characteristics of the conceptions (e.g. mother's education) by 30 day periods relative to the 30 days of Ramadan. We then then create indicator variables for the Ramadan period and for the three 30 day periods preceding and following Ramadan. We first purge the dependent variables of calendar month and calendar year effects and the regress the residuals on the indicators for the seven 30 day periods (with no constant). For log conceptions we also include mother's education and mother's age and age squared

ful.[41] Although, we do not have direct measures of family income in our data, we do know if the source of payment for the birth utilized Medicaid. Figure 8 shows that there are no meaningful or statistically significant changes in Medicaid usage for Arab conceptions that took place around Ramadan. Once again, it appears that low SES women are less likely to conceive prior to Ramadan and more likely to conceive after Ramadan. Figure 9 shows the pattern in log conceptions around Ramadan along with 95 percent confidence bands. The chart highlights that rate of conceptions among Arabs falls slightly before and during Ramadan and then rises after Ramadan as expected. However, neither the Ramadan dip of -2.3 percent or the subsequent rise of 3.7 percent after Ramadan are statistically significant. In any case, given that the timing of conceptions around the Ramadan period are not selective with respect to observed measures of SES suggests that changing fertility is not a confounding factor. We contrast these charts with Figure 10 which shows a pronounced decline in the fraction of births that are male around Ramadan.

4.5 Heterogeneous Effects?

If Ramadan observance during pregnancy varied by socioeconomic or health status, treatments effects would presumably also show a corresponding gradient, other things equal. Interestingly, there is no systematic gradient in the magnitude of the estimated effects by maternal education, medicaid participation, or month prenatal care was initiated (results available from authors). If treatment effects of the fast are relatively homogeneous, this suggests that fasting observance is high or fairly uniform by month of gestation.

5 Uganda Results

5.1 Disability Outcomes

We begin by showing the results for disability outcomes for Muslims in Table 10. Because these outcomes have a low incidence rate 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 over each of the 9 months preceding birth. We find a statistically significant increase in the likelihood of a disability for Muslims born 9 months after Ramadan suggesting a link between exposure to Ramadan very early in pregnancy and compromised adult health. The point estimate is 0.819 (p-value = 0.02). Given the mean disability rate of 3.8 percent, the magnitude of the effect is large at 22 percent. We find that no other month prior to birth is statistically significant and the p-value on the

[41]There is a modest but statistically insignificant rise in education for mothers who conceive three months after Ramadan but some of these conceptions are likely to overlap with Ramadan in the following year.

joint test of all nine coefficients is far from significant. Moreover, we cannot reject that all of the coefficients are equal.

Looking across the specific types of disability, the most striking finding is that there is a particularly large effect on the incidence of a mental or learning disability (column 4) due to exposure during the first month of pregnancy. The point estimate is 0.250 with a p-value of 0.001. Given the mean rate of 0.14 percent this implies that the occurrence of Ramadan early in pregnancy nearly doubles the likelihood of a disability related to diminished cognitive function. Mental/learning disabilities are also statistically significant at the 5 percent level for those with exposure in month 8 and significant at the 10 percent level for those with exposure in months 5 or 6. For this outcome, the joint test on all gestation months can reject that there is no effect at the 4 percent significance level.

We also find that the incidence of sight/blindness and hearing/deafness 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) and 64 percent for deafness (p-value = 0.04).[42] For hearing/deafness we also find a marginally significant effect for those exposed to Ramadan in the fifth month of gestation.

We also tested the sensitivity of the results to also including exposure during the 10th month prior to birth and found that the results were unaffected and that in no case was the coefficient on the 10th month statistically significant. We also ran our specifications separately for men and women and found that the results were qualitatively similar though the estimates were much less precise. These additional results are available upon request.

In Table 11, we present the same exercise on our sample of Non-Muslims. We find no cases of a corresponding significant result for Muslims also occurring for Non-Muslims. We do estimate a few small but statistically significant effects for disabilities involving upper extremities for non-Muslims. We do not find this so surprising given that we should expect about 5 percent of our estimates to be significant purely by chance. There is also the possibility that this can be due to mis-specification due to inadequate controls for say location effects or seasonal effects. Therefore, we think that it is also important to inspect the data visually and to perform robustness checks to ensure that idiosyncratic cohort effects are not driving our results.

Taken as a whole, these results suggest that: i) there is evidence that exposure in the first month of pregnancy appears to have an effect on disability outcomes involving cognitive and sensory function and ii) there is a statistically significant effect of exposure to Ramadan across all gestation months on mental/learning disability. Since most of the fetal origins literature has focussed on adult disease outcomes such as diabetes and heart disease, it is not entirely clear how these results concerning disability should be interpreted.

[42]we also find that the having a disability involving a lower extremity is 27 percent but is only marginally significant (*p-value* = 0.11).

One could view these results as reflecting possible long-term effects of "accelerated starvation" as discussed in section 2.2.1. Neurological development occurs early in pregnancy and has been shown to be affected by exposure to ketones in animal studies. Since the neural tube lays the groundwork for the development of both aural and ocular function this could explain the results concerning vision and hearing. Previous research on diabetic mothers has linked hypoglycemia (low blood glucose) during the first trimester with diminished cognitive function (Rizzo *et al.*, 1991).

5.2 Causes of Disability

In Table 12 we look at the origins of disability. We group these factors by whether they can reasonably be linked to fasting via the mechanisms discussed earlier. Clearly, 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 extended periods of nutritional restriction may be associated with a reprogramming of the body's systems that result in poor health outcomes later in life. This would be consistent with those who report "aging" as the source of a disability. Since it is conceivable that fasting might contribute to a weakened immune system, respondents who report disabilities due to "disease" could plausibly be related to the timing of Ramadan. Finally, whether 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.[43]

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 nutritional restriction. 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. Since this result is consistent with the fetal origins hypothesis it bolsters the case that our main finding with respect to disabilities is not spurious. We also find no evidence linking the occurrence of Ramadan during gestation to disabilities that have origins in disease or that are congenital. We also ran the same specifications with our non-Muslim sample and with one exception, we found no statistically

[43]It is worth noting that animal studies suggest that exposure to ketones appears to be associated with slower neurological growth rather than neurological malformations (Moore *et al.*, 1989) and we found no hypothesized associations between fasting and congenital disabilities.

significant effects.[44] Importantly, we found no comparable effect of first month exposure to Ramadan on disabilities caused by aging for non-Muslims.

5.3 Human Capital and Labor Market Outcomes

Table 13 shows the results for human capital and labor market outcomes for Ugandan Muslims. We find only 3 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 those with the same timing of Ramadan exposure are also 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. The size 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. For non-Muslims we found a number of instances of statistically significant effects across the outcomes. However, the magnitudes of the point estimates are very small.[45] For example, non-Muslims born 4 months after Ramadan have about five hundredths of a year more schooling which is less than 1 percent higher than the mean but is very precisely estimated.

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.[46] 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 (Table 10). 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

[44] Among non-Muslims the only significant effect is that those exposed to Ramadan one month before birth are 0.12 percentage points (p-value = 0.017) more likely to have a congenital disability. This is a 20 percent effect relative to the mean.

[45] In each case the point estimates are within a standard error of the coefficient estimates for Muslims. This suggests that if we had the same precision for non-Muslims that we have for Muslims, none of the point estimates would be significant.

[46] 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. We do however, control for *calendar* month of birth effects.

residuals against our measure for first month exposure (*rampct9*) in Figure 11.[47] 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 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 in Figure 12, 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 coefficient with the outliers is 0.745, which corresponds to the estimate in Table 10 of 0.819. Without the outliers, the coefficient only falls slightly to 0.738. We also conduct a similar sensitivity check with mental/learning disability and find that removing outlier cohorts actually raises the point estimate on first gestation month exposure from 0.160 to 0.184. In addition, the standard errors are much lower without the outliers.

5.5 Effects on the Adult Sex Ratio

In this section we investigate the possibility that maternal fasting during the *in utero* period may influence the adult sex ratio. This could arise either because of alterations to the sex composition at birth or because of selective mortality by sex after birth as might be implied by some of the fetal origins literature. We aggregate the data by birth month and calculate population counts by gender. We then regress the male to female ratio and the fraction male on our Ramadan exposure measures using, weighted by the total size of the cells.

The results are shown in Table 14. In the first column we find that every gestational month has a negative coefficient, however, only the 7th month (three months prior to birth) is statistically significant at the 5 percent level. In the second column we also include the 10th month prior to birth to see if this captures any preconception effects. We find that the coefficient on the 10th month actually has a positive sign and its inclusion removes the significance of the 7th month.[48] In the second pair of columns we find a reduction in the fraction male that is statistically significant in three implied gestation months

[47] For our monthly measure of exposure (*rampct*) the numerical suffix refers to the number of months prior to birth. We have removed datapoints for which *rampct9* = 0 to simplify the the figure, all of the statistical results include these datapoints.

[48] This might be due to the fact that this specification considerably narrows the reference group to consist solely of those born 11 to 12 months after Ramadan.

(1, 4 and 7) when we do not include the 10th month prior to birth. In this case, when we add pre-conception exposure we continue to find that Ramadan exposure in the 7th month is associated with a reduction in the fraction male by about 2.1 percentage points.

The fact that we find no effect on the 10th month prior to birth in columns 2 and 4 might be reconciled with our Michigan results by virtue of the fact that the coefficient on the 9th month prior to birth may actually capture much of the critical preconception period for those born in the second half of their birth month or those who have a shorter gestational age. The last two columns show that we find no comparable effects for non-Muslims.

5.6 Selective Timing of Conceptions Around Ramadan, Uganda

We revisit the possibility of selective timing of conceptions with our Uganda data. Our results thus far have used a sample of adults at the time of the Uganda Census. Since we have no information on their *parents* characteristics we instead use a sample of children (under age 17) who were living with their parents at the time of the Census for thsi exercise. Our approach, once again is to graphically depict how the aggregate population counts and parental characteristics in our Uganda sample are related to Ramadan exposure around the time of conception. There are two major issues with this analysis compared with our Michigan data. First, we do not know actual gestation length with this data so there may be considerable error and possible bias is assuming normal gestation. Second, we cannot distinguish differences in the rate of births from subsequent mortality in these cohorts.

The results shown in figures 13 through 15 do not provide any indication that selection in the timing of conception accounts for our results. Mother's education and literacy levels appear to fluctuate randomly within a very tight band around zero. Interestingly, both Muslims and Non-Muslims display almost identical patterns in log conceptions around the Ramadan period (figure 15). Conceptions are flat prior to Ramadan, dip slightly (about 3 to 4 percent) in the month of Ramadan and then gradually increase in the months following Ramadan.

6 Conclusion

A vast and growing literature has begun to link the effects of early life events to long-term health and socioeconomic outcomes. We consider the short and long run effects of the timing of prenatal nutrition. Epidemiological studies of the fetal origins hypothesis (Barker, 1992) have generally used variation in prenatal nutrition from: 1) famine episodes, or; 2) cross-sectional differences (frequently proxied by low birth weight). In the first approach, although the nutritional shock may be unrelated to potential outcomes, the generalizability of estimates to less acute nutritional exposures is uncertain. In the second approach, an explicit reason for prenatal nutrition to vary across mothers is generally absent, and estimates may be confounded by factors correlated with prenatal nutrition differences (e.g. maternal education). The commonplace remedy of saturating a regression model with covariates is not satisfactory (Freedman, 1991) and can exacerbate omitted variables bias (Clarke, 2005).

In this study, we have attempted to combine the merits of these two approaches. Because of its idiosyncratic timing, the Ramadan fast constitutes a compelling research design – Ramadan appears unrelated to the characteristics of Muslim mothers and when they conceive children (or deliver). Furthermore, surveys indicate most pregnant Muslims fast when Ramadan falls during pregnancy. The recurrence of Ramadan approximately two weeks earlier each year means that most of the roughly 1.3 billion Muslims alive today were *in utero* during a Ramadan. Moreover, the Ramadan fast may exert similar health effects as meal skipping more generally: "accelerated starvation" has been found both for Ramadan fasting and generic meal skipping. Similarly, the large negative effect on the sex ratio of pre-conception diet found by Mathews *et al.* (2008) is mirrored by the large drop in the sex ratio for Arab mothers conceiving at the end of a Ramadan fast.

We conclude that fairly modest variation in nutrition due to temporary fasts exerts a substantial effect on the sex ratio and adult health. This sensitivity is especially pronounced near conception and in early pregnancy. Indeed, a reason relatively large effects are plausible is that insults at different stages of pregnancy have distinct effects; unlike most previous studies, we are able to assign the timing of the treatment to individual months of gestation. To the extent that investment decisions overlook the sensitivity to nutrition near conception, investments are sub-optimally low.

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Table 1: Summary of Hypotheses Concerning Outcomes Affected by Fasting and Timing In Utero

Outcome	Description of Mechanism (studies)	Gestation month
Birth Outcomes		
Birthweight	Direct effect of low blood glucose (Scholl et al, 2001)	6 to 7
Birthweight	Exposure to ketones, animal studies (Hunter, 1987; Moore, 1989)	1
Birthweight	HPA axis (various studies)	1 to 2
Birthweight	Low birthweight due to shorter gestation (Siega-Riz et al, 2001)	5 to 7
Birthweight	Empirical result --Dutch Famine (Painter et al 2005)	7 to 9
Low Birth Weight	Empirical result (Cross et al 1990; Arab, 2001)	4 to 6
Gestation	Fasting associated with high Plasma CRH (Siega-Riz et al, 2001)	5 to 7
NICU	empirical result (Mirghani and Hamud, 2006)	8
C-section	empirical result (Mirghani and Hamud, 2006)	8
Induced Labor	empirical result (Mirghani and Hamud, 2006)	8
Sex Ratio	Effect of low glucose, empirical result (Matthews et al, 2008)	0
Long-Term Outcomes		
Diabetes	Fetal nutrition (various studies)	
Heart Disease	Fetal nutrition (various studies)	
Cognitive Function	Exposure to ketones, animal studies (Hunter, 1987; Moore, 1989)	1
Cognitive Function	Low blood glucose (Rizzo et al, 1991)	1 to 3
Cognitive Function	HPA axis (Kapoor et al, 2006)	1 to 2
Cognitive Function	Fetal Heart Rate (Mirghani, 2005)	7 to 9
Adult Sex Ratio	HPA axis (Kapoor et al, 2006)	1 to 2

Notes: This table is based on a review of selected studies and does not include all relevant studies in the medical literature. Studies include both human and animal studies . in many of the studies, the period of in utero exposure was selected by design and therefore the fact that an effect was found in the chosen gestation period does not rule out possible effects in other periods.

Table 2: Summary Statistics for Michigan Natality Data, 1989-2005

	Arab			Non-Arab		
	mean	s.d.	N	mean	s.d.	N
Mother's Age	27.51	5.72	43436	27.39	5.72	1554328
Mother's Education	12.01	3.55	42183	13.17	2.35	1542208
Father's Age	33.78	6.45	42115	30.20	6.11	1386163
Father's Education	12.91	3.35	40636	13.40	2.38	1353624
Male Child	0.52	0.50	43439	0.51	0.50	1554480
Tobacco	0.04	0.20	42671	0.19	0.39	1527891
Alcohol	0.00	0.04	42638	0.02	0.12	1524993
Maternal Weight Gain	29.69	12.68	38931	31.01	12.98	1440370
Prenatal Care	0.99	0.10	41591	0.99	0.09	1525293
Medicaid	0.45	0.50	42894	0.27	0.44	1533801
Fraction Arab, Zipcode	0.21	0.25	42878	0.01	0.03	1530542
Birthweight	3328.08	512.40	43357	3429.87	565.66	1551493
Low Birthweight	0.04	0.21	43444	0.05	0.21	1554510
Parity	1.63	1.74	43076	1.39	1.49	1545247
Preterm	0.06	0.23	43341	0.07	0.25	1550156
Gestation	39.28	1.72	43341	39.31	1.85	1550156
Apgar 5 minute	8.94	0.55	43366	8.94	0.67	1549511
NICU	0.03	0.17	43371	0.04	0.19	1550379
Complication	0.24	0.43	42644	0.28	0.45	1534856
Abnormal Condition	0.06	0.23	42470	0.07	0.25	1527331
Medical Risk	0.18	0.39	42625	0.23	0.42	1534376
Medical Risk Diabetes	0.03	0.16	42625	0.03	0.17	1534376
Born January	0.077	0.27	43444	0.079	0.27	1554510
Born February	0.074	0.26	43444	0.077	0.27	1554510
Born March	0.084	0.28	43444	0.087	0.28	1554510
Born April	0.079	0.27	43444	0.084	0.28	1554510
Born May	0.084	0.28	43444	0.089	0.28	1554510
Born June	0.087	0.28	43444	0.086	0.28	1554510
Born July	0.090	0.29	43444	0.089	0.28	1554510
Born August	0.090	0.29	43444	0.088	0.28	1554510
Born September	0.087	0.28	43444	0.085	0.28	1554510
Born October	0.084	0.28	43444	0.083	0.28	1554510
Born November	0.081	0.27	43444	0.076	0.27	1554510
Born December	0.083	0.28	43444	0.079	0.27	1554510
Mo. 1, Ram Hrs Exposure	0.056	0.15	43341	0.056	0.15	1550156
Mo. 2, Ram Hrs Exposure	0.059	0.15	43341	0.058	0.16	1550156
Mo. 3, Ram Hrs Exposure	0.058	0.15	43341	0.059	0.16	1550156
Mo. 4, Ram Hrs Exposure	0.059	0.15	43341	0.060	0.16	1550156
Mo. 5, Ram Hrs Exposure	0.058	0.15	43341	0.060	0.16	1550156
Mo. 6, Ram Hrs Exposure	0.056	0.15	43341	0.060	0.16	1550156
Mo. 7, Ram Hrs Exposure	0.055	0.15	43341	0.061	0.16	1550156
Mo. 8, Ram Hrs Exposure	0.057	0.15	43341	0.061	0.16	1550156
Mo. 9, Ram Hrs Exposure	0.059	0.16	43341	0.060	0.16	1550156

Table 3: 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	0.0380	0.191	80924	0.0521	0.222	640825
blind/vision impaired	0.0106	0.102	80922	0.0149	0.121	640789
deaf/hearing impaired	0.0038	0.062	80923	0.0061	0.078	640781
mute/speech impaired	0.0009	0.030	80921	0.0015	0.038	640780
lower extremities	0.0125	0.111	80921	0.0161	0.126	640794
upper extremities	0.0039	0.062	80921	0.0056	0.075	640779
mental/learning	0.0014	0.037	80921	0.0017	0.041	640777
psychological	0.0014	0.038	80921	0.0020	0.045	640776
epilepsy	0.0005	0.023	80921	0.0009	0.031	640777
rheumatism	0.0009	0.030	80921	0.0016	0.039	640776
congen	0.0050	0.070	80921	0.0058	0.076	640778
disease	0.0203	0.141	80924	0.0283	0.166	640803
accident	0.0056	0.074	80921	0.0079	0.088	640782
occupational injury	0.0053	0.072	80921	0.0074	0.086	640786
war¨injury	0.0007	0.027	80921	0.0013	0.036	640777
aging	0.0053	0.072	80921	0.0074	0.086	640786
Born January	0.105	0.306	81197	0.096	0.294	643300
Born February	0.076	0.265	81197	0.075	0.263	643300
Born March	0.072	0.258	81197	0.072	0.259	643300
Born April	0.110	0.313	81197	0.106	0.308	643300
Born May	0.070	0.256	81197	0.070	0.256	643300
Born June	0.102	0.302	81197	0.105	0.307	643300
Born July	0.094	0.292	81197	0.098	0.298	643300
Born August	0.079	0.269	81197	0.083	0.275	643300
Born September	0.079	0.269	81197	0.081	0.272	643300
Born October	0.078	0.268	81197	0.077	0.267	643300
Born November	0.069	0.253	81197	0.069	0.253	643300
Born December	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 4: Effects of Ramadan Exposure on Birth Weight by Gestation Month, Michigan Arabs

Dependent Variable is Birthweight, Coefficients are on Ramadan Exposure measures (% of daylight hours, % of days)

Ramadan Exposure Assuming Normal Gestation						*Ramadan Exposure Using Gestation Data*			
	Use Exact Date of Birth				*Use Birth Month*				
Months prior to Birth	All Arabs % Daylight Hours	All Arabs % Daylight Hours	Exclude Chaldean % Daylight Hours	All Arabs % of Days	All Arabs % of Days	Gestation Month exposure	All Arabs % Daylight Hours	All Arabs % Daylight Hours	Exclude Chaldean % Daylight Hours
10	--	1.8		--	--	0	--	3.1	--
		(21.0)						(18.8)	
9	-50.6 ***	-50.3 **	-49.9 **	-34.3 ***	-11.1	1	-45.2 ***	-44.6 **	-44.1 **
	(19.5)	(19.8)	(23.3)	(13.2)	(13.4)		(17.5)	(17.8)	(20.8)
8	-40.4 **	-39.7 **	-51.1 **	-27.9 **	-41.2 ***	2	-25.5	-24.3	-37.0 *
	(18.5)	(20.2)	(22.2)	(12.8)	(13.0)		(16.7)	(18.1)	(19.9)
7	10.0	10.6	19.3	7.6	-7.6	3	-12.5	-11.5	-23.1
	(19.2)	(20.4)	(23.1)	(13.4)	(13.6)		(17.3)	(18.3)	(20.7)
6	-46.3 **	-45.7 **	-43.0 *	-33.0 **	-20.1	4	-15.5	-14.5	-14.4
	(19.3)	(20.5)	(23.2)	(13.5)	(13.6)		(17.3)	(18.4)	(20.8)
5	-2.5	-1.9	-8.9	-2.0	-19.9	5	-29.2 *	-28.3	-43.7 **
	(19.5)	(20.6)	(23.4)	(13.7)	(13.9)		(17.6)	(18.5)	(21.1)
4	-38.6 **	-38.1 *	-44.3 *	-28.8 **	-10.1	6	-35.0 **	-34.2 *	-38.5 *
	(19.4)	(20.3)	(23.2)	(13.7)	(13.8)		(17.6)	(18.4)	(21.1)
3	-33.1 *	-32.6	-18.4	-26.1 *	-29.6 **	7	-27.4	-26.5	-40.1 *
	(19.4)	(20.3)	(23.2)	(13.7)	(14.0)		(17.5)	(18.3)	(20.7)
2	-13.3	-12.8	-9.2	-12.1	-17.0	8	3.6	4.4	14.2
	(18.5)	(19.3)	(22.1)	(13.0)	(13.0)		(16.6)	(17.4)	(19.8)
1	5.2	5.8	12.4	4.0	-11.6	9	-23.9	-22.8	-40.2 **
	(18.9)	(20.3)	(22.5)	(13.2)	(13.4)		(16.9)	(18.2)	(20.1)
joint test, coefficients on months 1 to 9 equal to 0									
p-value	0.017	0.022	0.046	0.010	0.158		0.153	0.215	0.089
joint test, coefficients on months 1 to 9 are equal									
p-value	0.056	0.058	0.074	0.039	0.668		0.441	0.439	0.3331
N	42097	42097	30367	42097	42097		39193	39193	28240

Table 5: Effects of Ramadan Exposure on Birth Weight by Gestation Month, Michigan Arabs

Coefficients are on Ramadan exposure to % daylight hours.

Gestation Month exposure	*Birthweight* — Samples include gestation lengths of … 25-42 weeks		27-42 weeks		31-42 weeks		35-42 weeks		39-42 weeks	
1	-44.3	**	-45.4	**	-42.3	**	-48.7	***	-50.3	***
	(19.2)		(18.9)		(18.4)		(17.7)		(19.6)	
2	-32.3	*	-31.2	*	-28.7		-22.7		-35.9	*
	(18.3)		(18.0)		(17.5)		(16.9)		(18.5)	
3	-5.9		-6.5		-6.2		-19.1		-17.8	
	(19.0)		(18.7)		(18.2)		(17.5)		(19.2)	
4	-10.2		-11.5		-12.6		-12.3		-36.3	*
	(19.0)		(18.7)		(18.2)		(17.5)		(19.3)	
5	-42.1	**	-38.6	**	-27.9		-32.6	*	-38.6	**
	(19.3)		(19.0)		(18.5)		(17.8)		(19.7)	
6	-40.8	**	-41.6	**	-43.9	**	-43.3	**	-20.6	
	(19.3)		(19.0)		(18.4)		(17.8)		(19.5)	
7	-36.0	*	-32.5	*	-30.0		-31.6	*	-35.4	*
	(19.2)		(18.9)		(18.4)		(17.7)		(19.5)	
8	23.4		21.2		17.2		8.5		-1.3	
	(18.3)		(18.0)		(17.5)		(16.9)		(18.6)	
9	-27.8		-26.2		-26.1		-27.0		-32.3	*
	(18.5)		(18.2)		(17.7)		(17.1)		(18.8)	
joint test, all shaded coeff equal to 0										
p-value	0.057		0.036		0.063		0.030		0.163	
joint test, all shaded coeff are equal										
p-value	0.242		0.261		0.412		0.136		0.693	
N	41624		41567		41405		40888		28991	

Table 6: Effects of Ramadan Exposure on Gestational Age by Gestation Month, Michigan Arabs

Coefficients are on Ramadan exposure to % daylight hours.

	Gestational Age									
Gestation Month exposure	Samples include gestation lengths of … 25-42 weeks		27-42 weeks		31-42 weeks		35-42 weeks		39-42 weeks	
1	-0.06		-0.06		-0.05		-0.07		-0.02	
	(0.07)		(0.06)		(0.06)		(0.05)		(0.04)	
2	-0.05		-0.04		-0.03		0.00		-0.06	*
	(0.06)		(0.06)		(0.05)		(0.05)		(0.03)	
3	0.00		0.00		0.02		-0.05		-0.07	*
	(0.06)		(0.06)		(0.06)		(0.05)		(0.04)	
4	-0.02		-0.02		-0.03		-0.04		-0.04	
	(0.06)		(0.06)		(0.06)		(0.05)		(0.04)	
5	-0.15	**	-0.13	**	-0.08		-0.08		-0.08	**
	(0.07)		(0.06)		(0.06)		(0.05)		(0.04)	
6	-0.04		-0.04		-0.06		-0.06		-0.03	
	(0.07)		(0.06)		(0.06)		(0.05)		(0.04)	
7	0.02		0.05		0.06		0.04		0.03	
	(0.06)		(0.06)		(0.06)		(0.05)		(0.04)	
8	0.07		0.06		0.04		0.00		-0.08	**
	(0.06)		(0.06)		(0.05)		(0.05)		(0.03)	
9	0.01		0.02		0.01		0.02		-0.02	
	(0.06)		(0.06)		(0.06)		(0.05)		(0.03)	
joint test, all shaded coeff equal to 0										
p-value	0.276		0.475		0.511		0.490		0.082	
joint test, all shaded coeff are equal										
p-value	0.320		0.591		0.443		0.458		0.266	
N	41686		41627		41464		40946		29038	

Table 7: Effects of Ramadan Exposure on Birth Weight by Gestation Month, Michigan Non-Arabs

Dependent Variable is Birthweight, Coefficients are on Ramadan Exposure measure of % of daylight h

Exposure Assuming Normal Gestation				*Exposure Using Gestation Data*		
Months prior to Birth	All Non-Arabs % Daylight Hours		Exclude Arab Zipcodes % Daylight Hours	Gestation Month exposure	All Non-Arabs % Daylight Hours	Exclude Arab Zipcodes % Daylight Hours
9	-2.6		16.4	1	-4.5	18.4
	(3.5)		(12.5)		(3.4)	(12.3)
8	-3.3		5.5	2	0.7	8.5
	(3.3)		(11.9)		(3.3)	(11.7)
7	-4.5		11.2	3	-1.6	18.2
	(3.4)		(12.2)		(3.3)	(12.0)
6	-2.0		2.5	4	-4.2	0.8
	(3.4)		(12.2)		(3.3)	(11.9)
5	-6.5	*	13.8	5	-1.1	6.2
	(3.4)		(12.3)		(3.3)	(12.0)
4	-1.9		1.3	6	-2.2	1.1
	(3.4)		(12.3)		(3.3)	(12.0)
3	-5.8	*	9.7	7	-3.2	-7.0
	(3.4)		(12.1)		(3.3)	(11.8)
2	0.5		11.2	8	-1.0	10.5
	(3.2)		(11.6)		(3.2)	(11.4)
1	1.6		-2.1	9	-3.4	-2.9
	(3.3)		(12.0)		(3.3)	(11.8)
joint test, coefficients on months 1 to 9 equal to 0						
p-value	0.483		0.924		0.924	0.711
joint test, coefficients on months 1 to 9 are equal						
p-value	0.576		0.969		0.964	0.7205
N	1539135		120775		1057700	83759

Table 8: Effects of Ramadan Exposure on Sex Ratio at Birth by Months Relative to Conception, Michigan Arabs and Non

Coefficients are on Ramadan Exposure measures of % of daylight hours

	Arab Samples				*Non-Arab Samples*	
Gestation Month exposure (1 is conception)	All Arabs		Exclude Chaldean Zipcodes		All Non-Arabs	
	Male/Fem Ratio	Fraction Male	Male/Fem Ratio	Fraction Male	Male/Fem Ratio	Fraction Male
-1	0.09	0.018	0.15	0.032	-0.01	-0.003
	(0.10)	(0.023)	(0.12)	(0.027)	(0.02)	(0.004)
0	-0.20 **	-0.044 *	-0.27 **	-0.060 **	0.01	0.003
	(0.10)	(0.023)	(0.12)	(0.027)	(0.02)	(0.004)
1	0.01	0.005	-0.06	-0.013	0.01	0.003
	(0.10)	(0.024)	(0.13)	(0.028)	(0.02)	(0.004)
2	-0.06	-0.012	-0.06	-0.012	-0.01	-0.003
	(0.10)	(0.023)	(0.12)	(0.027)	(0.02)	(0.004)
3	0.00	0.002	0.00	0.003	0.02	0.005
	(0.10)	(0.024)	(0.13)	(0.028)	(0.02)	(0.004)
4	-0.03	-0.010	-0.04	-0.012	-0.01	-0.002
	(0.10)	(0.022)	(0.12)	(0.027)	(0.02)	(0.004)
5	0.10	0.023	-0.04	-0.006	0.00	0.000
	(0.10)	(0.022)	(0.12)	(0.026)	(0.02)	(0.004)
N	203	203	203	203	203	203

Table 9: Effects of Ramadan Exposure on Other Birth Outcomes by Gestation Month, Michigan Arabs

Gestation Month exposure	Low Birth Weight	5-minute APGAR score	Maternal Weight Gain	Neonatal Intensive Care Unit	C-section	Pregnancy Complication	Abnormal Conditions	Congenital Anomaly
1	-0.001	-0.012	-0.136	-0.001	0.002	-0.030*	0.003	0.004
	(0.006)	(0.016)	(0.519)	(0.005)	(0.014)	(0.017)	(0.009)	(0.005)
2	0.006	-0.001	0.358	-0.001	0.012	0.012	-0.008	0.002
	(0.005)	(0.015)	(0.493)	(0.005)	(0.013)	(0.016)	(0.008)	(0.005)
3	0.003	-0.013	-0.106	0.003	-0.004	0.011	0.006	-0.008
	(0.006)	(0.016)	(0.510)	(0.005)	(0.014)	(0.017)	(0.009)	(0.005)
4	-0.003	0.011	0.018	-0.007	0.011	0.004	-0.005	0.000
	(0.006)	(0.016)	(0.513)	(0.005)	(0.014)	(0.017)	(0.009)	(0.005)
5	-0.002	0.004	0.118	-0.005	-0.023	0.01	-0.009	-0.005
	(0.006)	(0.016)	(0.518)	(0.005)	(0.014)	(0.017)	(0.009)	(0.005)
6	0.009*	-0.007	0.291	0.000	0.030**	0.002	0.011	0.004
	(0.006)	(0.016)	(0.519)	(0.005)	(0.014)	(0.017)	(0.009)	(0.005)
7	0.004	-0.002	-0.381	0.001	0.004	-0.007	-0.004	-0.003
	(0.006)	(0.016)	(0.517)	(0.005)	(0.014)	(0.017)	(0.009)	(0.005)
8	-0.004	0.006	0.597	0.006	0.002	0.003	0.001	0.002
	(0.005)	(0.015)	(0.492)	(0.005)	(0.013)	(0.016)	(0.008)	(0.005)
9	0.003	-0.024	-0.472	0.003	0.016	0.014	0.017**	0.000
	(0.005)	(0.015)	(0.499)	(0.005)	(0.013)	(0.016)	(0.008)	(0.005)
joint test, coefficients on months 1 to 9 equal to 0								
p-value	0.540	0.820	0.920	0.530	0.340	0.560	0.300	0.730
joint test, coefficients on months 1 to 9 are equal								
p-value	0.470	0.770	0.880	0.430	0.310	0.470	0.230	0.640
N	39250	39199	35653	39185	38891	38514	38351	38355

Table 10: Effects of Ramadan Exposure on Disability Outcomes, Ugandan Muslims by Months Prior to Birth

Entries are the coefficient times 100 on Ramadan exposure in each month prior to birth, "rampct"

Months Prior to Birth	Disability	Sight/Blind	Hearing/Deaf	Mental/ Learning	Psychological	Lower Extremities	Upper Extremities
9	0.819**	0.349*	0.243**	0.250***	-0.098	0.334	-0.071
	(0.359)	(0.193)	(0.117)	(0.071)	(0.072)	(0.211)	(0.119)
8	0.087	-0.078	0.162	0.103	-0.068	0.057	0.008
	(0.337)	(0.180)	(0.110)	(0.066)	(0.067)	(0.197)	(0.112)
7	-0.132	-0.022	0.13	0.028	0.058	-0.316	0.077
	(0.349)	(0.187)	(0.114)	(0.069)	(0.069)	(0.204)	(0.115)
6	0.197	0.074	0.161	0.1	-0.098	-0.15	0.085
	(0.353)	(0.189)	(0.115)	(0.070)	(0.070)	(0.207)	(0.117)
5	0.085	-0.004	0.197*	0.129*	-0.058	-0.045	-0.036
	(0.348)	(0.187)	(0.114)	(0.069)	(0.069)	(0.204)	(0.115)
4	0.273	0.039	0.072	0.117*	-0.049	0.033	0.179
	(0.352)	(0.189)	(0.115)	(0.070)	(0.070)	(0.206)	(0.117)
3	0.104	0.124	0.099	0.039	-0.009	-0.118	-0.029
	(0.364)	(0.195)	(0.119)	(0.072)	(0.073)	(0.214)	(0.121)
2	-0.266	-0.272	0.026	0.144**	-0.019	-0.059	0.001
	(0.350)	(0.187)	(0.114)	(0.069)	(0.070)	(0.205)	(0.116)
1	-0.103	0.018	0.086	0.089	-0.034	-0.058	-0.056
	(0.366)	(0.196)	(0.120)	(0.072)	(0.073)	(0.214)	(0.121)
joint test, coefficients on months 1 to 9 equal to 0							
p-value	0.390	0.560	0.480	0.040	0.740	0.380	0.830
joint test, coefficients on months 1 to 9 are equal							
p-value	0.310	0.460	0.830	0.290	0.750	0.310	0.770
Mean	3.80%	1.06%	0.38%	0.14%	0.14%	1.25%	0.39%
N	80924	80922	80923	80921	80921	80921	80921

Table 11: Effects of Ramadan Exposure on Disability Outcomes, Ugandan Non-Muslims by Months Prior to Birth

Entries are the coefficient times 100 on Ramadan exposure in each month prior to birth, "rampct"

Months Prior to Birth	Disability	Sight/Blind	Hearing/Deaf	Mental/ Learning	Psychological	Lower Extremities	Upper Extremities
9	-0.023	-0.052	0.028	-0.037	0.045	-0.039	0.051
	(0.146)	(0.080)	(0.052)	(0.028)	(0.030)	(0.084)	(0.050)
8	-0.015	-0.043	0.043	-0.005	-0.028	0.034	0.096**
	(0.137)	(0.075)	(0.049)	(0.026)	(0.028)	(0.079)	(0.047)
7	-0.074	-0.142*	-0.006	-0.006	0.01	0.097	-0.038
	(0.142)	(0.078)	(0.051)	(0.027)	(0.029)	(0.082)	(0.049)
6	-0.091	0.082	-0.007	-0.017	0.017	-0.082	0.012
	(0.144)	(0.079)	(0.051)	(0.027)	(0.029)	(0.083)	(0.049)
5	0.209	-0.111	0.051	0.034	0.006	0.074	0.125**
	(0.143)	(0.079)	(0.051)	(0.027)	(0.029)	(0.082)	(0.049)
4	-0.09	-0.03	0.048	-0.004	-0.017	-0.01	-0.019
	(0.144)	(0.079)	(0.051)	(0.027)	(0.029)	(0.083)	(0.049)
3	0.003	0.115	-0.018	-0.004	0.01	-0.002	0.003
	(0.147)	(0.081)	(0.053)	(0.028)	(0.030)	(0.085)	(0.051)
2	0.039	-0.015	0.065	-0.043	0.036	-0.019	0.015
	(0.142)	(0.078)	(0.051)	(0.027)	(0.029)	(0.082)	(0.049)
1	0.208	-0.061	0.035	0.01	0.023	0.122	0.123**
	(0.148)	(0.082)	(0.053)	(0.028)	(0.030)	(0.085)	(0.051)
joint test, coefficients on months 1 to 9 equal to 0							
p-value	0.670	0.290	0.890	0.560	0.650	0.730	0.040
joint test, coefficients on months 1 to 9 are equal							
p-value	0.570	0.240	0.910	0.490	0.580	0.650	0.050
Mean	5.21%	1.49%	0.61%	0.17%	0.20%	1.61%	0.56%
N	640825	640789	640781	640777	640776	640794	640779

Table 12: Effects of Ramadan Exposure on Causes of Disabilities, Ugandan Muslims, by Months Prior to Birth

Entries are the coefficient times 100 on Ramadan exposure in each month prior to birth, "rampct"

Months Prior to Birth	Unrelated to prenatal nutrition			Possibly Related to prenatal nutrition		
	Accident	Occ. Injury	War Injury	Aging	Disease	Congenital
9	-0.060	0.059	0.054	0.373***	0.199	0.059
	(0.142)	(0.074)	(0.052)	(0.136)	(0.267)	(0.074)
8	0.042	-0.023	0.001	0.137	-0.025	-0.023
	(0.133)	(0.070)	(0.049)	(0.127)	(0.250)	(0.070)
7	-0.102	-0.063	0	-0.034	-0.248	-0.063
	(0.137)	(0.072)	(0.050)	(0.132)	(0.259)	(0.072)
6	-0.025	0.05	0.043	0.222*	-0.369	0.05
	(0.139)	(0.073)	(0.051)	(0.134)	(0.262)	(0.073)
5	0.127	-0.009	-0.085*	-0.022	0.1	-0.009
	(0.137)	(0.072)	(0.050)	(0.132)	(0.258)	(0.072)
4	0.179	0.018	0.064	0.055	-0.252	0.018
	(0.139)	(0.073)	(0.051)	(0.133)	(0.261)	(0.073)
3	-0.09	0.031	0.047	0.11	0.006	0.031
	(0.144)	(0.075)	(0.053)	(0.138)	(0.270)	(0.075)
2	0.161	-0.063	0.021	-0.011	-0.158	-0.063
	(0.138)	(0.072)	(0.050)	(0.132)	(0.259)	(0.072)
1	0.002	-0.086	0.057	0.051	-0.044	-0.086
	(0.144)	(0.076)	(0.053)	(0.138)	(0.271)	(0.076)
joint test, coefficients on months 1 to 9 equal to 0						
p-value	0.710	0.730	0.460	0.210	0.750	0.730
joint test, coefficients on months 1 to 9 are equal						
p-value	0.640	0.640	0.400	0.210	0.730	0.640
Mean	0.56%	0.53%	0.07%	0.53%	2.03%	0.50%
N	80924	80922	80923	80921	80921	80921

Table 13: Effects of Ramadan Exposure on Human Capital Outcomes, Ugandan Muslims by Months Prior to Birth

Entries are the coefficient on Ramadan exposure in each month prior to birth, "rampct"

Months Prior to Birth	Illiterate	Years of School	No Schooling	Employed	Elementary Occupation
9	0.008	-0.088	-0.004	0.000	-0.005
	(0.008)	(0.068)	(0.007)	(0.009)	(0.005)
8	-0.015**	0.119*	-0.007	-0.001	0.003
	(0.007)	(0.064)	(0.007)	(0.008)	(0.005)
7	0.007	-0.009	0.001	-0.009	-0.006
	(0.008)	(0.066)	(0.007)	(0.009)	(0.005)
6	-0.014*	0.01	-0.013*	0.013	0.004
	(0.008)	(0.067)	(0.007)	(0.009)	(0.005)
5	0.012	-0.015	0.005	-0.019**	-0.013***
	(0.008)	(0.067)	(0.007)	(0.009)	(0.005)
4	0.008	-0.045	0.006	-0.001	-0.003
	(0.008)	(0.067)	(0.007)	(0.009)	(0.005)
3	0.002	0.061	-0.002	0.005	-0.003
	(0.008)	(0.069)	(0.008)	(0.009)	(0.005)
2	0.009	0.069	0.009	-0.002	-0.002
	(0.008)	(0.067)	(0.007)	(0.009)	(0.005)
1	0.005	-0.011	-0.005	0.001	-0.007
	(0.008)	(0.069)	(0.008)	(0.009)	(0.005)
joint test, coefficients on months 1 to 9 equal to 0					
p-value	0.100	0.440	0.390	0.460	0.340
joint test, coefficients on months 1 to 9 are equal					
p-value	0.070	0.380	0.300	0.380	0.360
Mean	0.30	6.94	0.25	0.66	0.04
N	78990	60117	80142	74348	46284

Table 14: Effects of Ramadan Exposure on Adult Sex Ratio by Months Prior to Birth, Uganda

Coefficients are on Ramadan Exposure measures of % of days, *rampct*

Months Prior to Birth	Muslims Male/Fem Ratio		Muslims Male/Fem Ratio	Muslims Fraction Male		Muslims Fraction Male		Non-Muslims Male/Fem Ratio		Non-Muslims Fraction Male
10	--		0.06	--		0.014		--		--
			(0.05)			(0.011)				
9	-0.08	*	-0.06	-0.019	**	-0.016	*	-0.01		-0.002
	(0.05)		(0.05)	(0.010)		(0.010)		(0.02)		(0.004)
8	-0.05		-0.03	-0.015		-0.009		-0.01		-0.001
	(0.04)		(0.05)	(0.009)		(0.010)		(0.02)		(0.004)
7	-0.01		0.01	-0.002		0.003		0.00		0.000
	(0.04)		(0.05)	(0.009)		(0.010)		(0.02)		(0.004)
6	-0.07		-0.05	-0.022	**	-0.017	*	0.02		0.006
	(0.04)		(0.05)	(0.009)		(0.010)		(0.02)		(0.004)
5	-0.05		-0.03	-0.015		-0.010		-0.03	*	-0.006
	(0.04)		(0.05)	(0.009)		(0.010)		(0.02)		(0.004)
4	-0.06		-0.04	-0.016	*	-0.011		0.01		0.002
	(0.04)		(0.05)	(0.009)		(0.010)		(0.02)		(0.004)
3	-0.10	**	-0.07	-0.025	***	-0.021	**	-0.01		-0.003
	(0.05)		(0.05)	(0.010)		(0.010)		(0.02)		(0.004)
2	-0.03		-0.01	-0.009		-0.005		0.00		-0.001
	(0.04)		(0.05)	(0.009)		(0.010)		(0.02)		(0.004)
1	-0.02		0.01	-0.009		-0.003		-0.01		-0.003
	(0.05)		(0.05)	(0.010)		(0.011)		(0.02)		(0.004)
joint test, coefficients on months 1 to 9 equal to 0										
p-value	0.456		0.745	0.115		0.398		0.679		0.687
joint test, coefficients on months 1 to 9 are equal										
p-value	0.856		0.804	0.637		0.576		0.637		0.601
Mean	1.051		1.051	0.506		0.506		1.018		0.502
N	627		627	654		654		654		654

Figure 1: Women's Weight Change Around Ramadan in Gambia

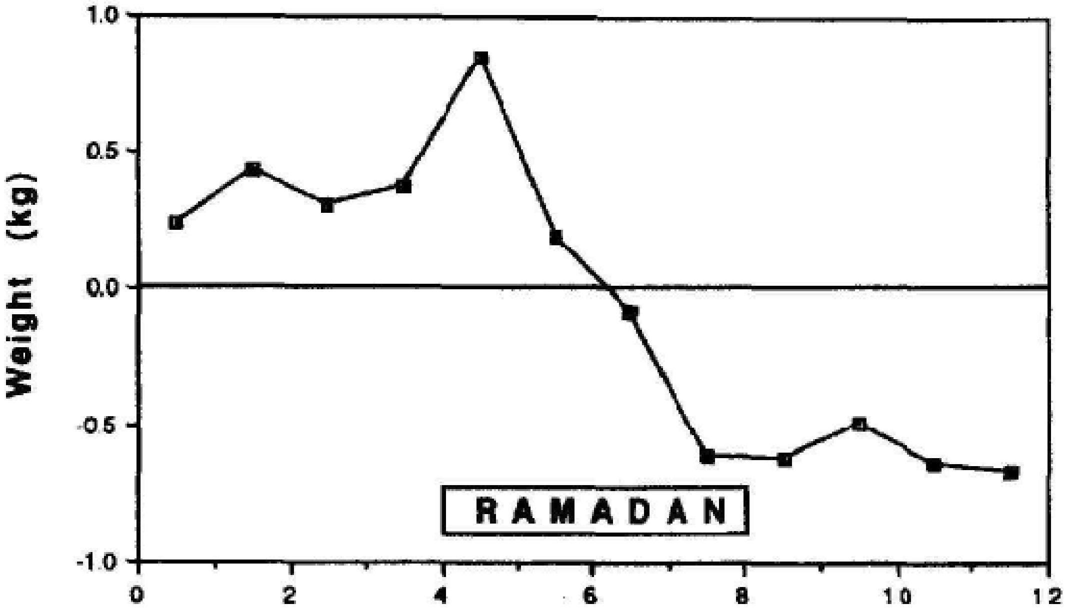
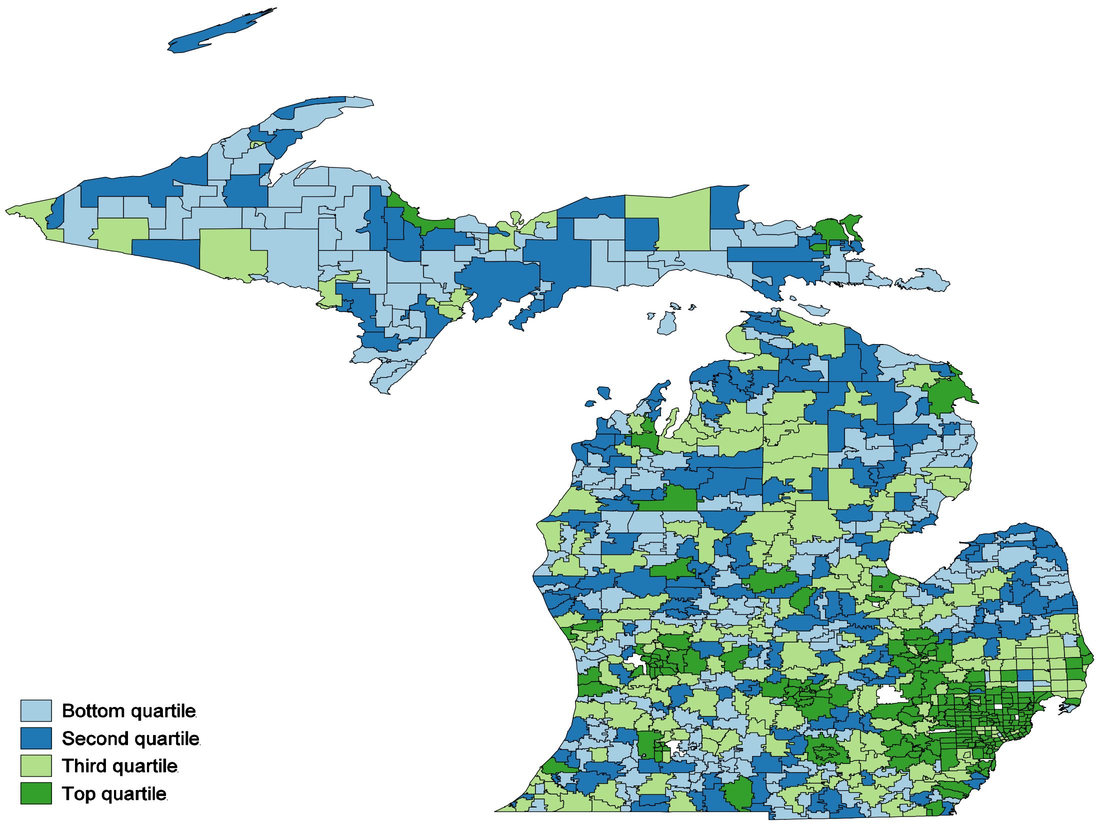


Fig. 8.5. Weight change in Gambian women during 3 months around the fast of Ramadan, expressed relative to mean weight for the other 9 months of the year. Each point has a standard error of about 0.15 kg. The data are adjusted for calendar month and year of measurement, and stage of pregnancy/lactation, using within-subject regression.

Source: Cole (1993)

Figure 2: Michigan Arab Population by Zipcode

Panel A: Quartiles of the Arab Population



Panel B: Ratio of the Chaldean to Arab Population

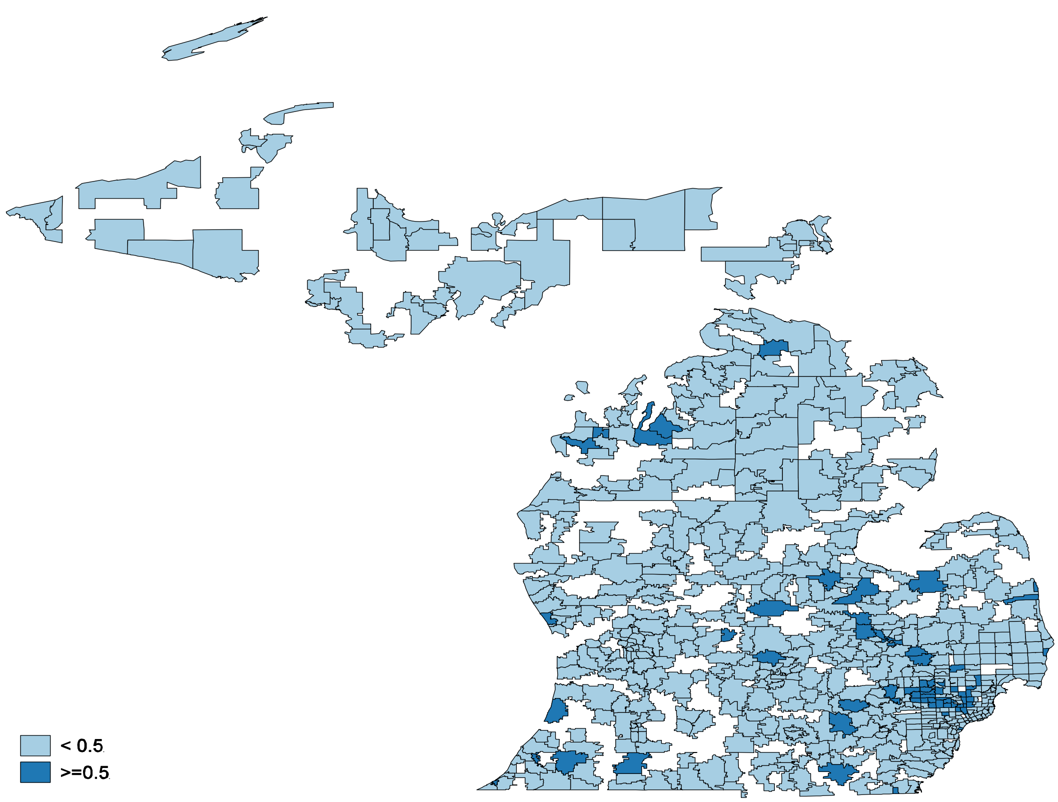


Figure 3: Muslim Share of Total Population, Uganda by District

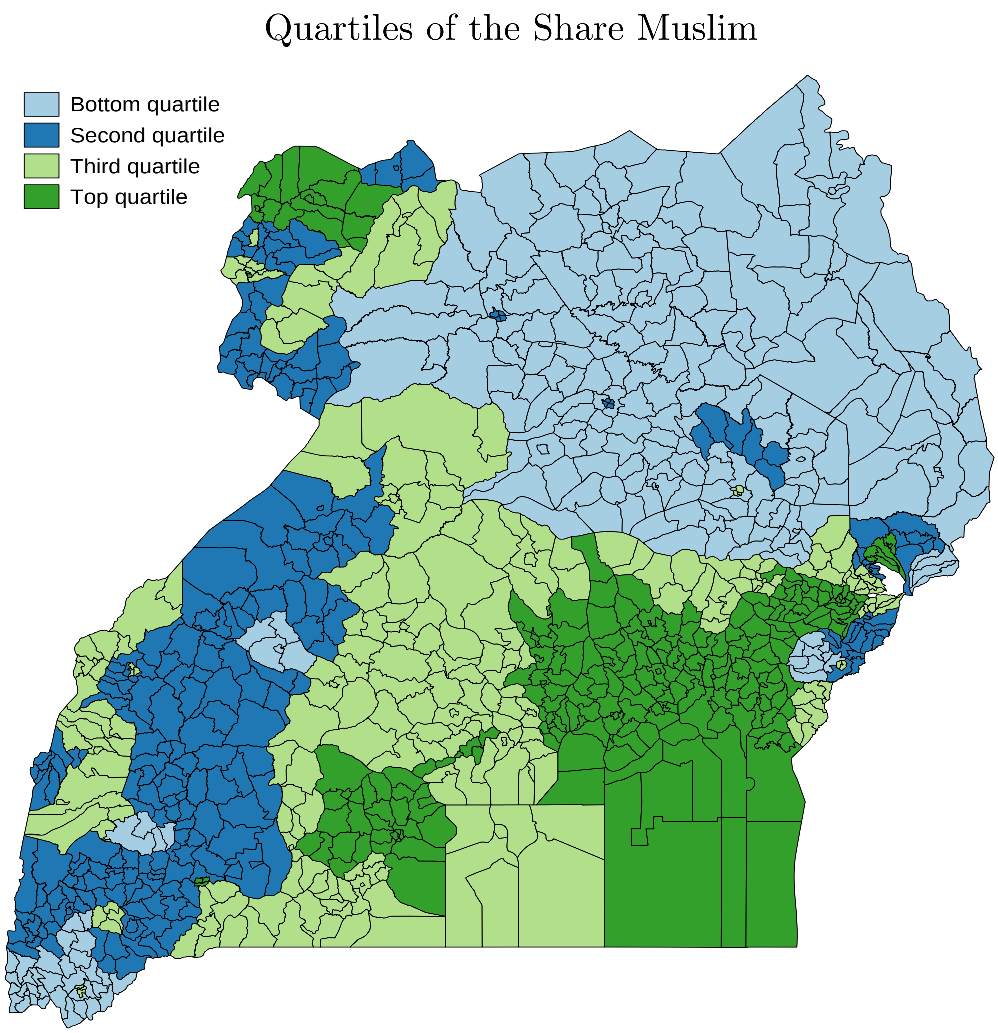


Figure 4: Uganda 2002 Census: Sample Size by Age

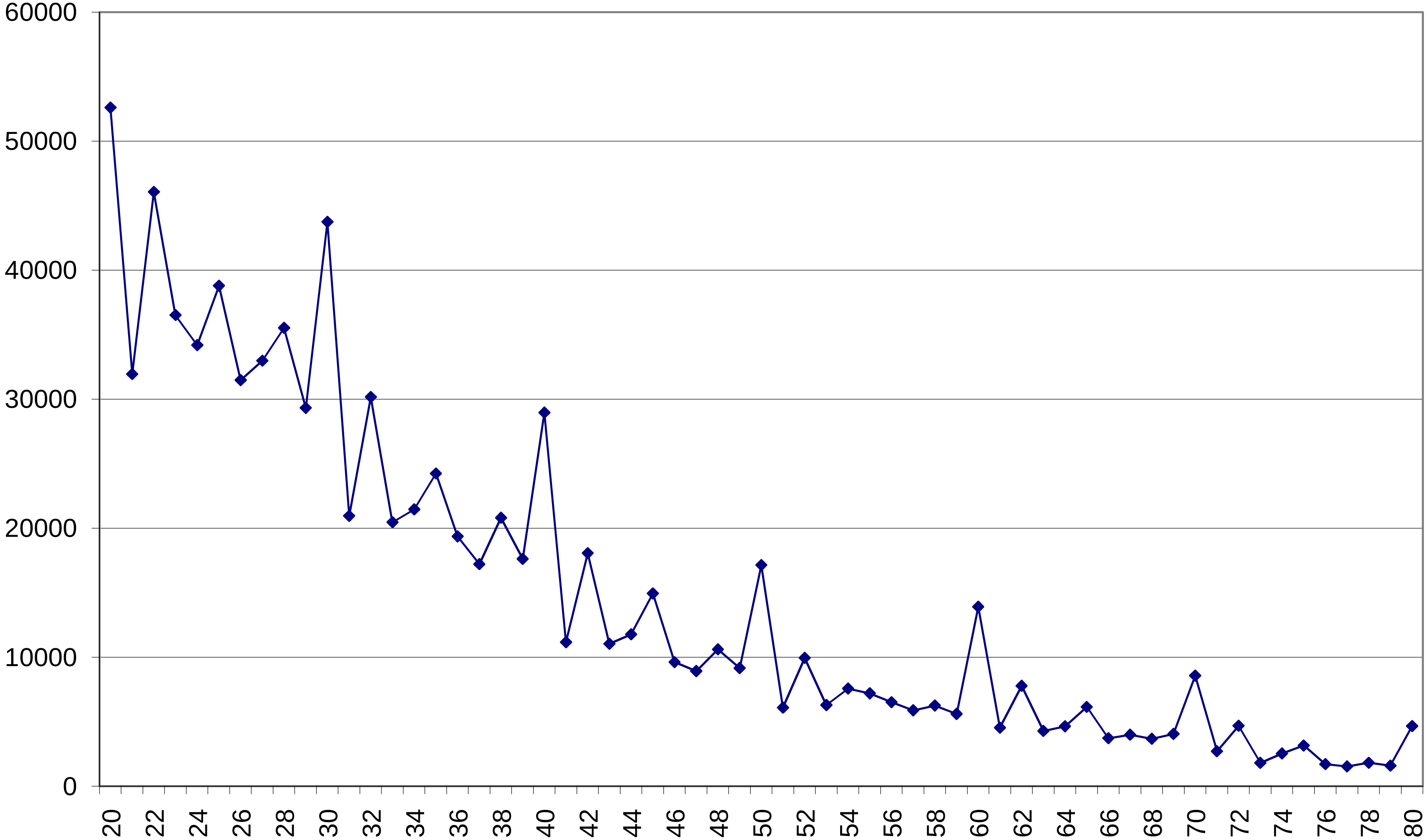


Figure 5: Example of Ramadan Exposure During First Month of Gestation

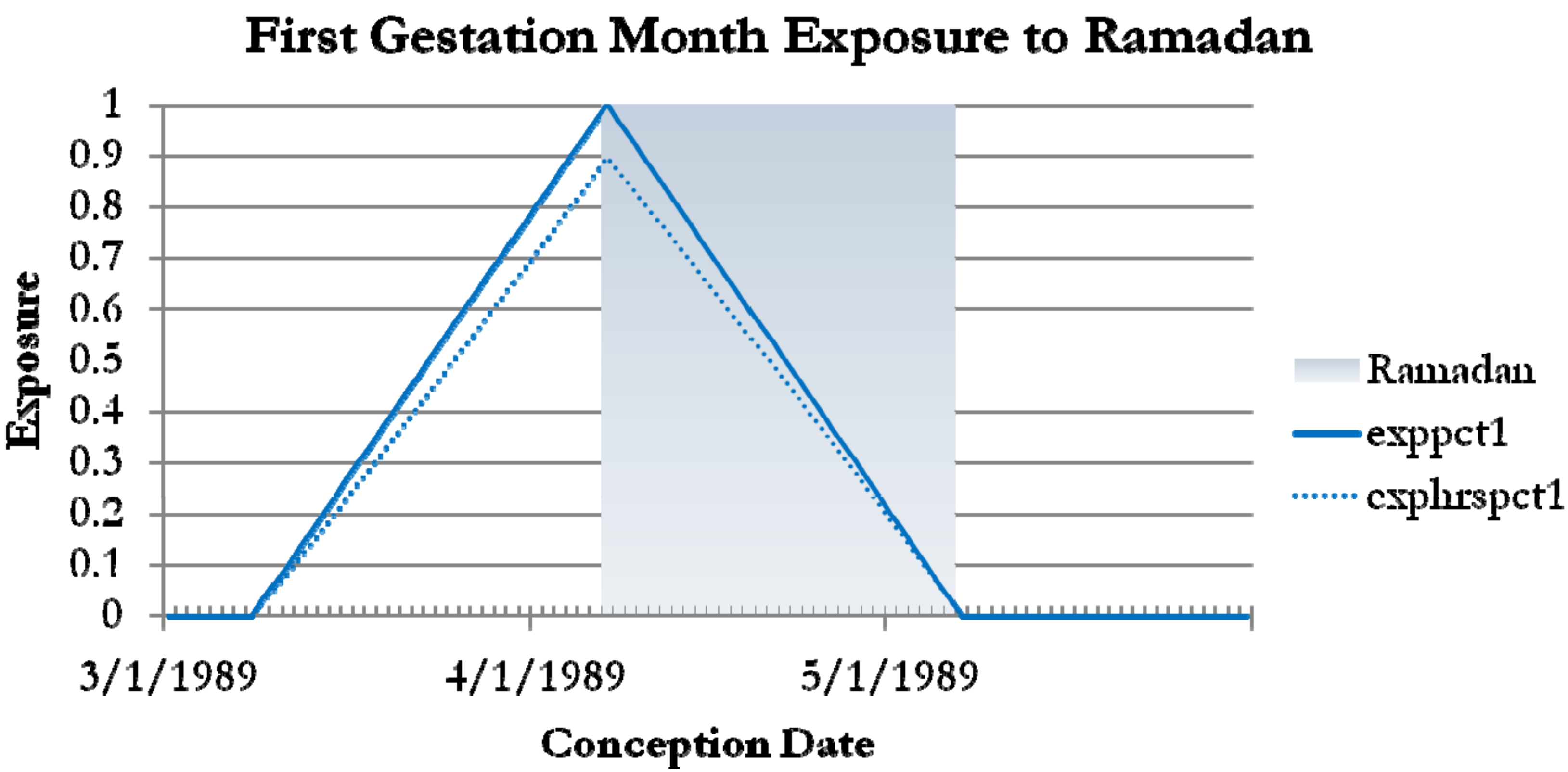


Figure 6: Distributional Effects of 1st month Exposure on Birthweight

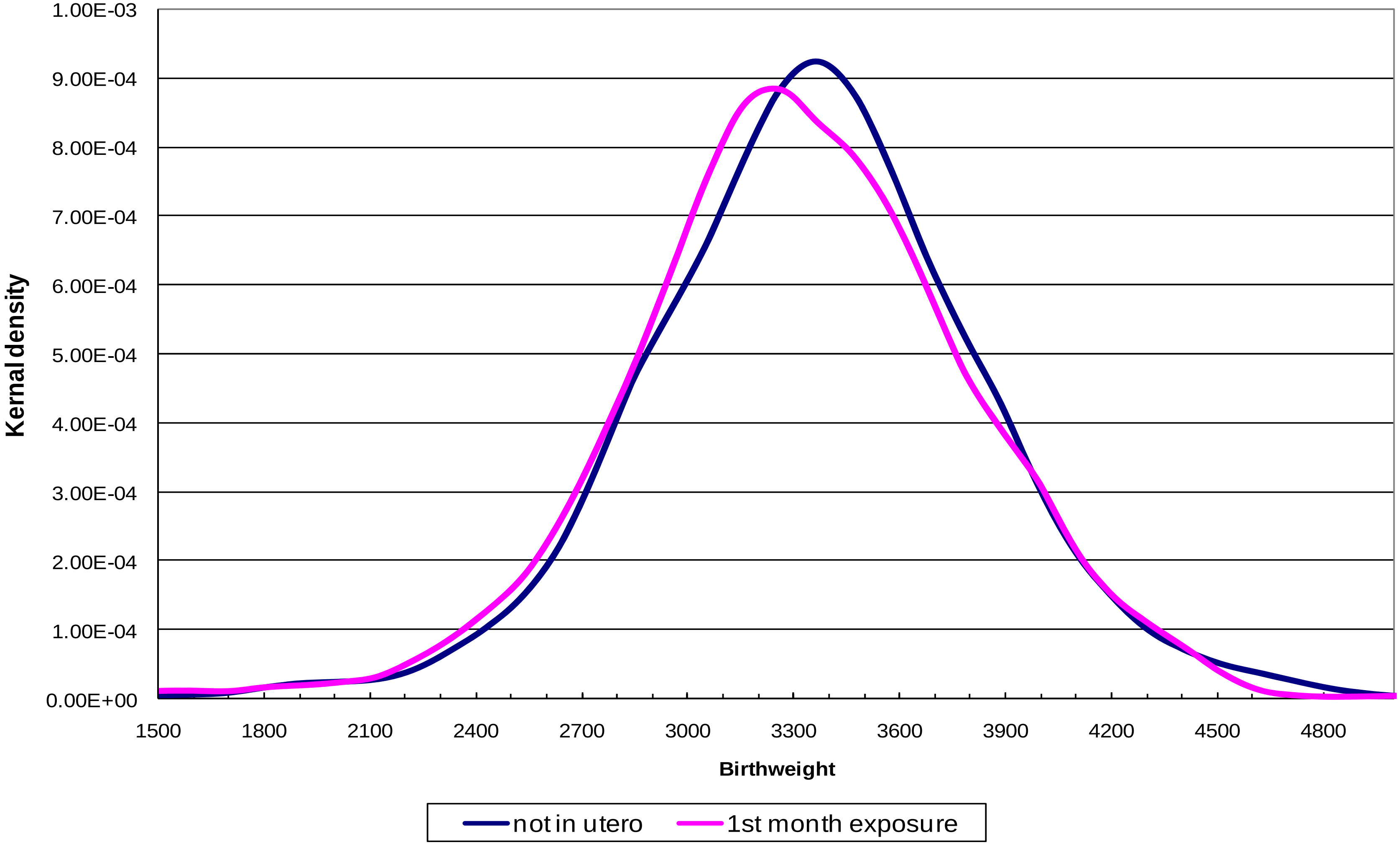


Figure 7: Mean Mother's Education
Conceptions Around Ramadan

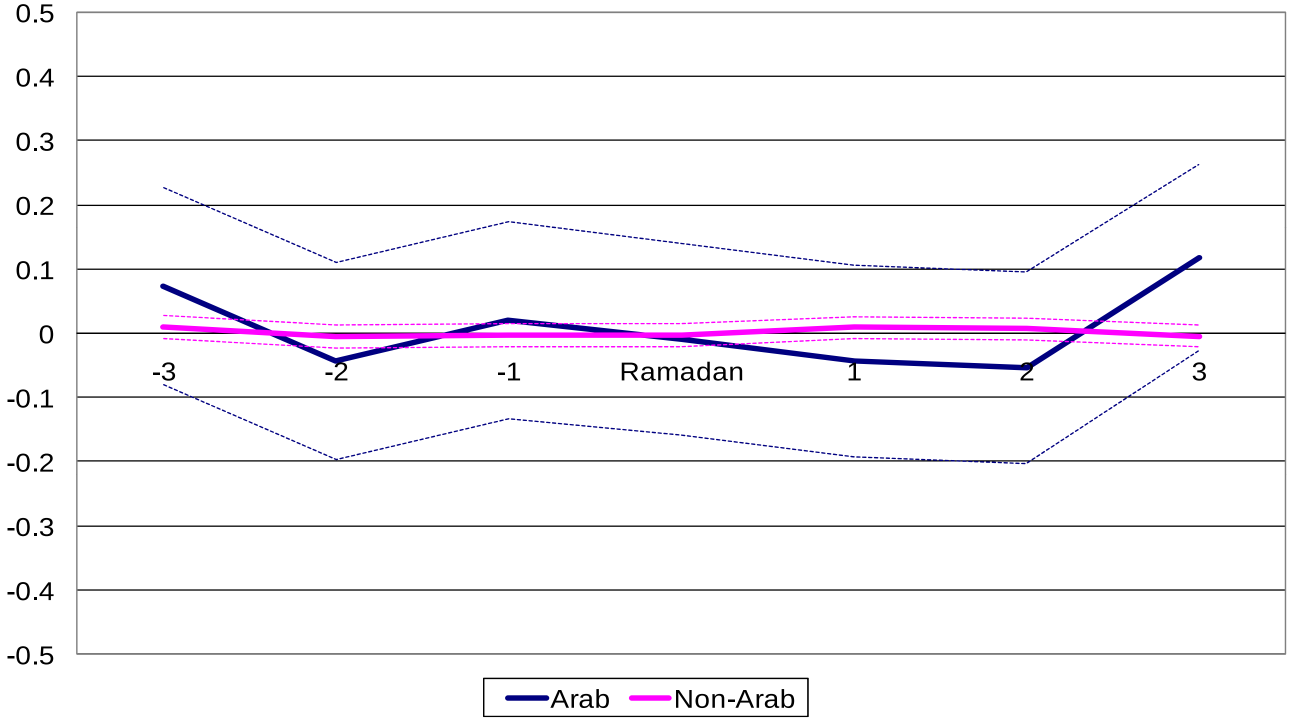


Figure 8: Mean Medicaid Use
Conceptions Around Ramadan

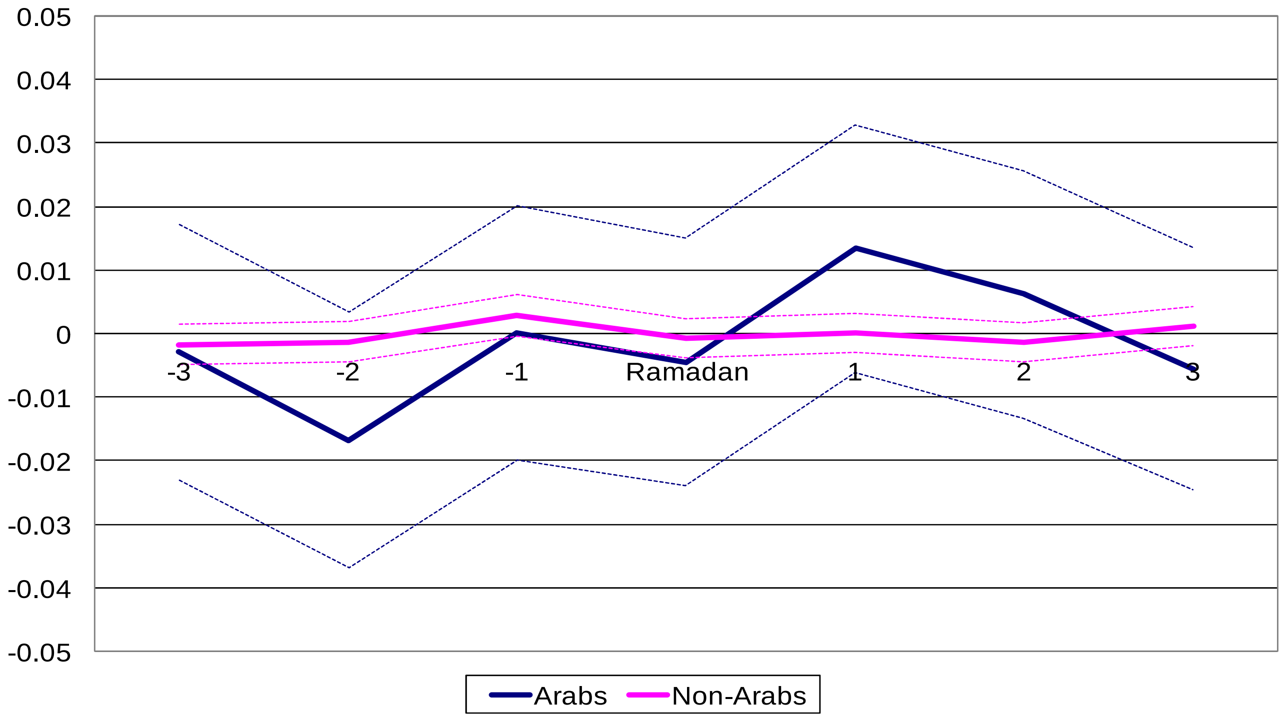


Figure 9: Log Conceptions Around Ramadan,
Relative to Baseline (other 5 months)

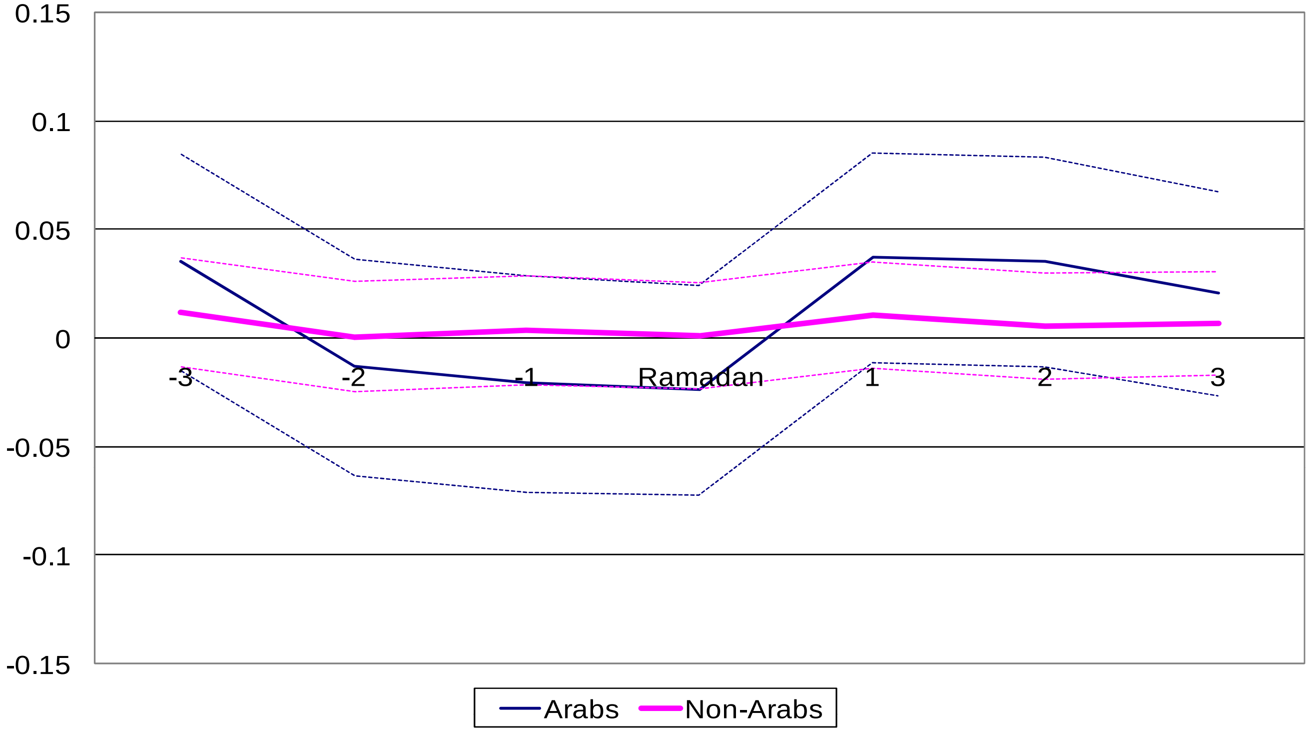
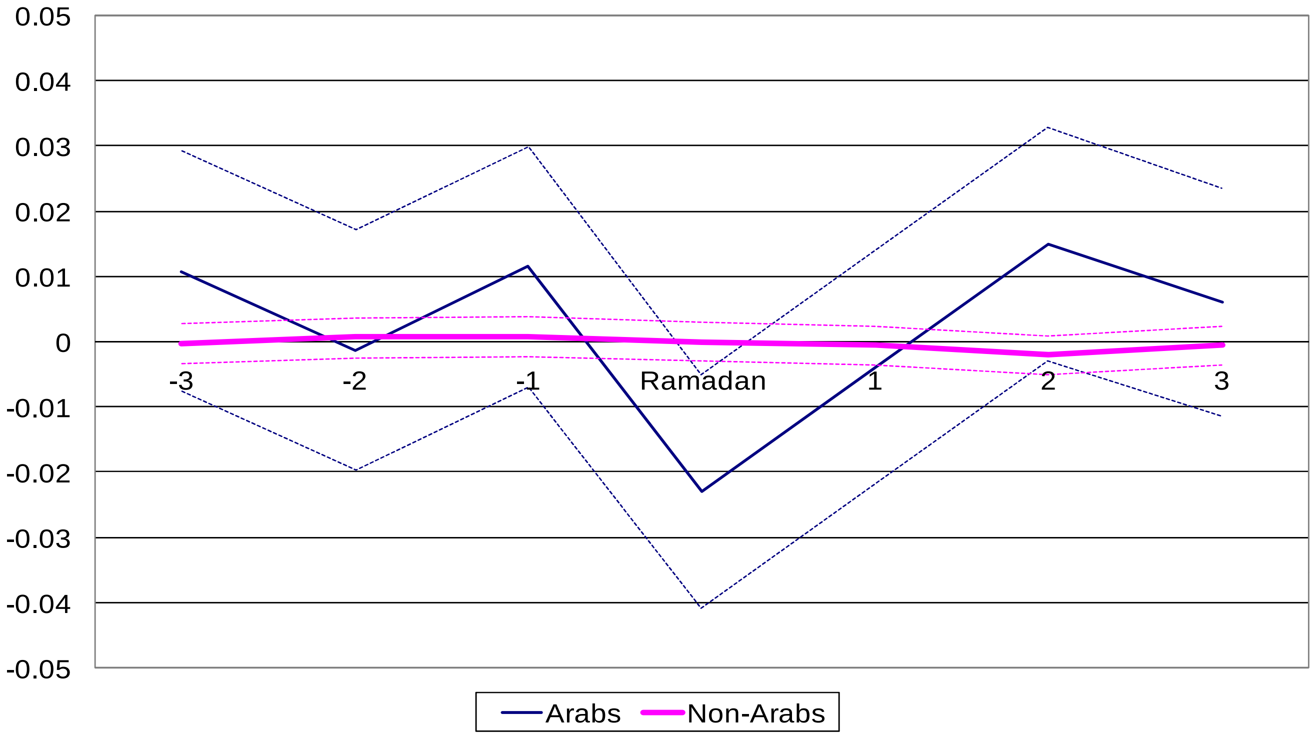


Figure 10: Male Fraction of Conceptions Around Ramadan,
Relative to Baseline (other 5 months)



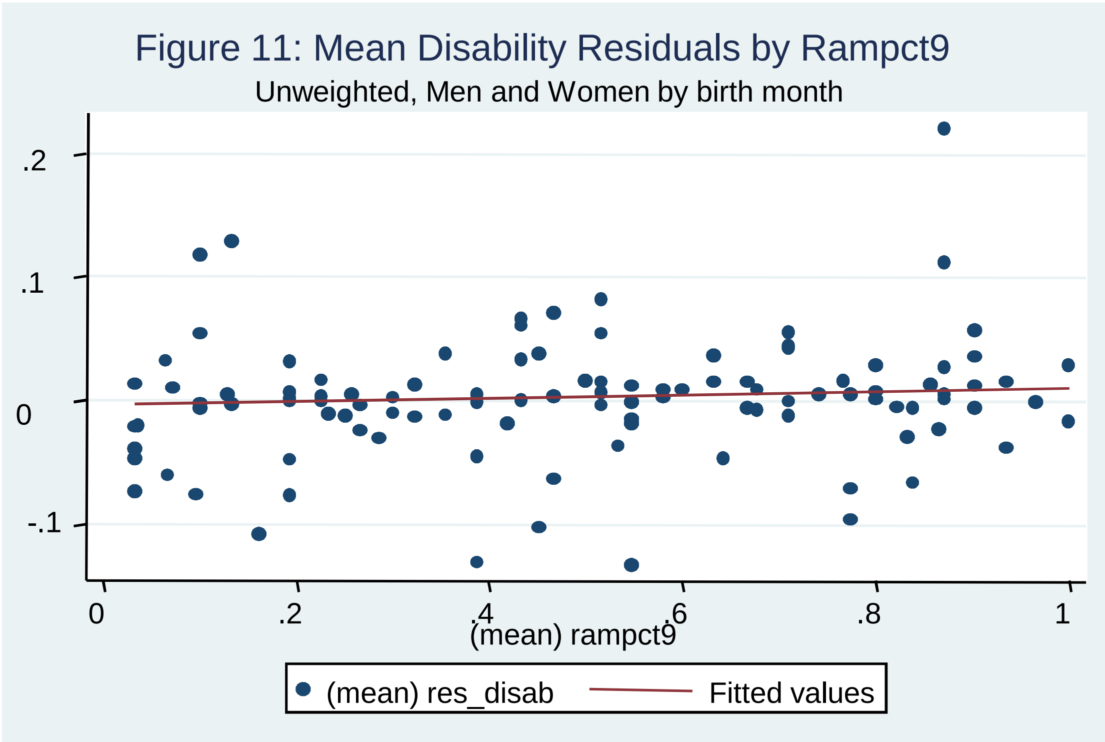


Figure 11: Mean Disability Residuals by Rampct9
Unweighted, Men and Women by birth month
.2
.1
0
-.1
0
.2
.4
.6
.8
1
(mean) rampct9
(mean) res_disab
Fitted values

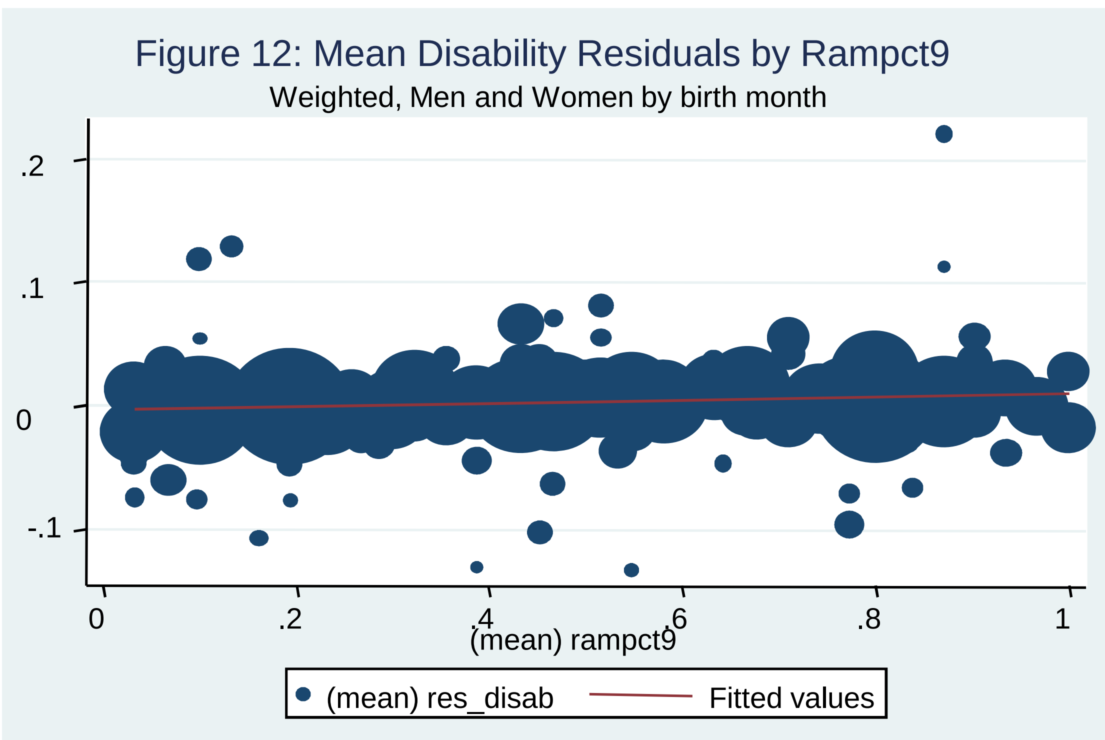


Figure 12: Mean Disability Residuals by Rampct9
Weighted, Men and Women by birth month
.2
.1
0
-.1
0
.2
.4
.6
.8
1
(mean) rampct9
(mean) res_disab
Fitted values

Figure 13: Mean Mother's Education Conceptions Around Ramadan

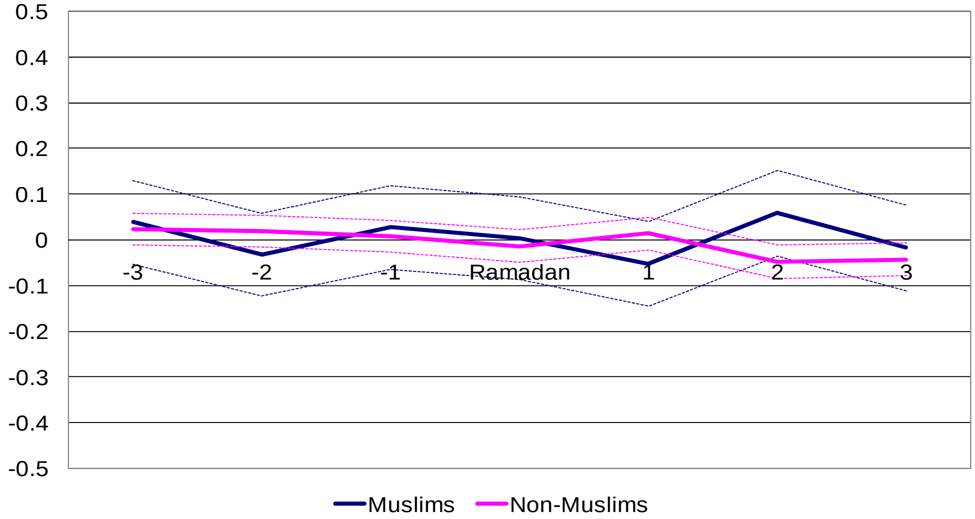


Figure 14: Mean Mother's Illiteracy, Uganda Conceptions Around Ramadan

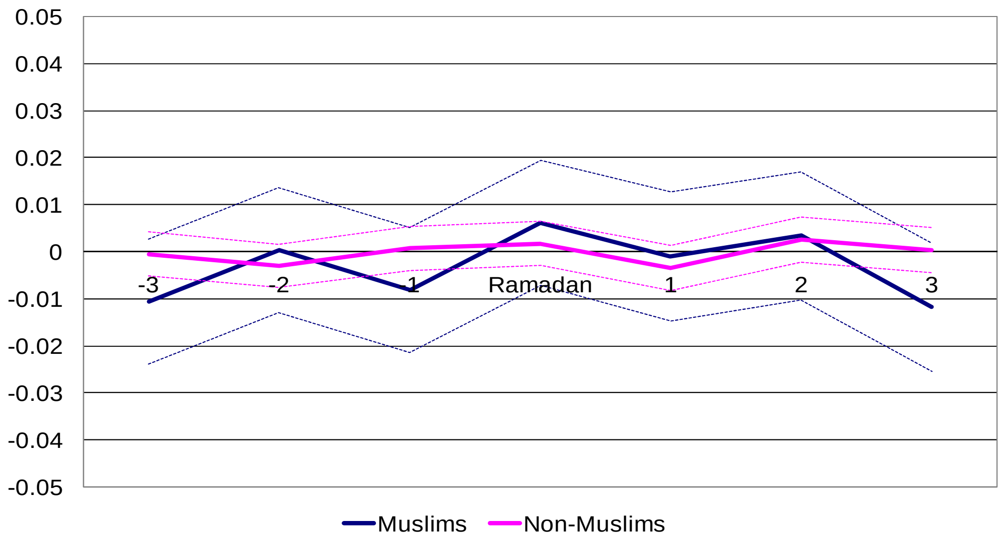


Figure 15: Log Conceptions Around Ramadan, Uganda Relative to Baseline (other 5 months)