Nutritional deficiency and infants' health outcomes

By Hossein SHAHRI [a†]

Abstract. Previous studies show that prenatal shocks to embryos could have adverse impacts on health endowment at birth. Using the universe of birth data and a difference-in-difference-in-difference strategy, I find that exposure to Ramadan during prenatal development has negative birth outcomes. Exposure to a full month of fasting is associated with 96 grams lower birth-weight. These results are robust across specifications and do not appear to be driven by mothers' selective fertility.

Keywords. Birth weight, Fetal origin hypothesis, Nutrition, Ramadan, Health, Religion.
JEL. I12, J13, Z12, D13.

1. Introduction

Nutrition is the main contributor to the environmental elements that generate the fetal genome. A nutritional distortion may lead the fetus to adopt in a way that alters the structure and physiology of the newborn, which, in turn, affects later-life outcomes. This process of self-adaptation and so-called *fetal programming* is the basis of the theory of *Fetal Origin* (Almond & Currie, 2011; Wu, *et al.*, 2004). Investigating the fetal roots of later life outcomes has recently captured attention among health economists (Behrman & Rosenzweig, 2004; Hoynes *et al.*, 2011; Myrskylä, 2010; NoghaniBehambari *et al.*, 2020a, 2020b; Sorensen *et al.*, 1999; Tavassoli *et al.*, 2020). For instance, (Hoynes *et al.*, 2015) explore the effect of reforms of Earned Income Tax Credit as a source of permanent shock to income of the disadvantaged population and find that the improvements in the welfare had potential to improve birth outcomes.

A small strand of this literature evaluates the effect of Ramadan observance during antenatal development as a form of gentle malnutrition (Almond, Mazumder, & Van Ewijk, 2014; Jürges, 2015; Majid, 2015). Using Michigan natality detailed files (1989-2006) and a difference-in-difference strategy, Almond & Mazumder (2011) (hereafter AM) find that exposure to a full month of Ramadan among Arab mothers (versus non-Arabs) in Michigan during pregnancy is associated with, on average, 18 grams lower birth-weight and roughly 6 percentage point lower fraction of male births.

[a†] Department of Environment, Texas Tech University, 2500 Broadway, TX 79409, USA.
☎. +1-409-454-7711 ✉. hossein.shahri@ttu.edu

The reduction in birth-weight is more pronounced during first trimester (20 grams) and second trimester (25 grams).

I improve their findings using US natality detailed files over the years 2004-2017and applying a difference-in-difference-in-difference identification strategy. I find that a full-month exposure to Ramadan reduces the birth-weight by 80-110 grams. The effects are larger than those of AM by a factor of 3 to 4. There are threepotential drivers for the observed difference. First, they recognize Muslims based on the race (Arabs VS non-Arabs). Since the current data asks for mother's birth country, I can distinguish the religion using aggregate distribution of Muslims in home-country. In fact, when I restrict the sample to Arab mothers in Michigan the estimated coefficients are very close to those of AM. Second, Arabs in Michigan are highly geographically gathered[2]. Using all Muslim mothers in Michigan will provide coefficients two-times larger than those of Arab mothers. Third, there is very limited variation of day-light hours across geographic locations in AM. The nationwide nature of the current data provides a much larger dosage of day-time exposure. Daylight hours vary from about 9.6 hours (Alaska, 2004) to 15.9 hours (Ohio, 2017). Ramadan occurs at lunar calendar and moves back about ten days each year. It allows for a source of variation of exposure over time. The across-state and over-time variation of the treatment in the data is much deeper than AM and provides more refined estimates.

Similar to AM, the main drawback of the data is that it lacks information about whether mothers did actually observe Ramadan. Therefore, the estimates must be interpreted as an intention-to-treat effect and a minimum causal effect. However, some researchers have found that 50-90% of pregnant Muslim mothers do observe Ramadan (e.g., Joosoph, *et al.*, 2004; Mubeen, *et al.*, 2012; and for US: Robinson & Raisler, 2005).

2. Data, sample selection and empirical method

The data are extracted from US Natality Detailed files 2004-2017. The sample is restricted to singleton birth records who reach full-term gestational age. I also restrict the sample to mothers who were definitely exposed to a full month of Ramadan and those who were surely not exposed. I use OLS regressions of the following form:

$$y_{itmc} = \alpha + \sum_{k=1}^{3} \beta^k \text{ExpH}ours_{tmc}^k + \pi X_{itmc} + \emptyset Z_{ct} + \mu_t + \gamma_m + \rho_c + \epsilon_{itmc} \quad (1)$$

Hours of exposure to Ramadan, $ExpHours$, vary over each trimester k, the birth years t, month of gestation m, and also based on the latitude of the county c. Some mother and father characteristics are included in X. In Z, I include some county-by-yearcharacteristics. The set of β^k are the coefficients of interest that capture the effect of hours of exposure on the outcome. I also report the results for a continuous variable that indicates

---

[2]About 80% of Arabs in Michigan reside in only three counties.

the total hours of exposure. Hourly exposures are divided by the average Ramadan hours over the sample period.

3. Results

A summary statistics of the final sample is reported in Table 1. On average, birth weight of infants is 3,327 grams. The main resultsof regressions introduced in equation 1 are reported in Table 2. The first column focuses on AM's sample. The estimates are quite close to their findings. In column 2, I restrict the sample to Michigan-resident immigrant mothers from countries in which Muslims' share exceeds 90%. The coefficients are almost two times larger. In column 3, the results for all US Muslims are reported. A full month exposure is associated with 138 grams fewer birth-weight. I use two non-Muslim groups as potential control groups: immigrants from non-Muslim countries (column 4) and US-born whites (column 5). There is no significant effect of exposure on their birth outcome. In order to rule out the seasonality effects, I apply a difference-in-difference strategy using non-Muslim immigrants as control group (column 6) and US-born mothers as control group (column 7). While the results of the latter control group is very close to that of Muslim samples only (128 grams reduction in birth-weight) the coefficients of DD using the former control group is smaller (75 grams reduction). One concern is that the seasonality effects act different for immigrants (Muslim and non-Muslims) compared to US-born mothers. To address this issue, I use a difference-in-difference-in-difference strategy by interacting an indicator of being immigrant and an indicator of being Muslim to all right-hand-side variables except the county dummies. The results are reported in column 9. A full month of exposure during first, second, and third trimester is associated with 82.3, 79.8, and 109.5 grams lower birth-weight, respectively. These effects are much larger than AM but comparable to findings of Savitri *et al.*, (2014) who find that Ramadan fasting among Muslim mothers reduces birth-weight by about 272 grams. The effects are also similar to findings of Haeck & Lefebvre (2016) who investigate the effect of egg-milk-orange program, a nutritional program for pregnant women, on birth outcomes. They find that the nutritional support could increase the birth-weight by 70 grams.

As a falsification test, I assign US-born mothers a fake Muslim status and non-Muslim immigrants serve as the control group. The DD results are reported in column 8. None of the coefficients is statistically significant and economically large.

Another concern is that mothers might target their pregnancy timing to avoid any overlap with Ramadan. If some characteristics of mothers, like education, make them more health conscious to avoid untimely pregnancy and meanwhile these characteristics affect the birth-weight, then the OLS results are biased. I try to address this issue by using mother's education, a proxy of mother's characteristics and socioeconomic status, as the outcome in equation 1. Results of single sub-sample, DiD, and DiDiD strategy

(reported in Table 3) rule out this possibility. Although the coefficients on Muslim mothers are relatively large, they are positive and insignificant.

4. Conclusion

Using a sample of over 16M births from US natality files 2004-2017 and a DiDiD strategy, I find that exposure to a full month of fasting among Muslim mothers is associated with, on average, 96 grams lower birth-weight. This is in line with previous literature but the point estimates are larger than those found by AM. The DiDiD strategy and the falsification tests rule out the possibility that my findings are driven by seasonality effects or the fact that the time trend effects act differently for immigrant mothers versus US-born mothers.

Overall, the estimates are intention-to-treat effects in a reduced form analysis. Not having information about the first stage effects, one might interpret the coefficients with caution since the real causal effects might be larger. If only 75% of Muslim mothers did observe Ramadan (a number within empirical range of 50-90%), the results imply a negative effect of 128 grams, or a 3.7% decrease from the mean birth-weight among Muslims.

Appendix

Table 1. *Summary Statistics*

Variable	Observations	Mean	Std. Dev.	Min	Max
Infant Characteristics:					
Birth Weight (grams)	16,547,046	3327.982	602.795	227	8165
Gestational Weeks	16,547,046	39.043	2.700	17	52
Sex (f=1)	16,547,046	0.488	0.497	0	1
Mother Characteristics:					
Age	16,547,046	26.465	5.886	10	54
Race: White	16,547,046	0.796	0.402	0	1
Race: Black	16,547,046	0.160	0.367	0	1
Unmarried	16,547,046	0.283	0.450	0	1
Education (Years of Schooling)	16,547,046	12.625	2.654	0	17
Month Prenatal Care Began	16,547,046	2.596	1.517	0	9
Prenatal Visits	16,547,046	11.179	4.025	0	49
State Characteristics:					
GSP per capita	16,547,046	43585.268	9031.635	24371.631	140143.05
Personal Income per capita	16,547,046	371.483	66.910	212.533	624.262
%Blacks	16,547,046	12.653	8.174	.222	69.376
%Whites	16,547,046	83.354	8.514	27.002	99.301
%Males	16,547,046	48.827	0.709	46.263	53.005
%Population 25-65	16,547,046	50.716	2.344	40.368	55.143
Log Current Transfer Receipt	16,547,046	18.080	0.991	14.495	19.850
Log Income Maintenance Benefits	16,547,046	15.830	1.131	11.503	17.908
Log Unemployment Insurance Benefits	16,547,046	14.594	1.119	10.697	16.796
Log Other Welfare Benefits	16,547,046	17.923	0.978	14.056	19.657
Minimum Wage	16,547,046	7.481	0.813	6.266	11.409

Notes. The data covers the years 2004-2017. All dollar values are converted into 2000 dollars to reflect real values.

Table 2. *Prenatal Ramadan Exposure and Birth Outcomes*

	Michigan Arabs	Michigan Muslims	All US Muslims	Immigrants Non-Muslims	US Born Whites	DD (3-4)	DD (3-5)	DD (4-5)	DDD (3-4-5)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
				Outcome: Birth-weight					
Ramadan	-24.62*	-55.15***	-138.23**	-10.30	2.53	-74.75**	-127.56***	5.43	-96.03***
Hours	(14.05)	(14.38)	(62.25)	(12.41)	(5.84)	(32.41)	(32.35)	(11.75)	(32.78)
R²	0.07	0.08	0.08	0.05	0.06	0.05	0.06	0.06	0.06
Observations	17,603	16,866	215,815	3,983,943	12,347,288	4,199,758	12,563,103	16,331,231	16,547,046
Mean DV	3390.54	3351.63	3388.45	3434.24	3483.25	3431.86	3481.59	3471.24	3470.14
				Ramadan Hours During					
First Trimester	-13.42	-37.28**	-105.89*	-11.39	1.94	-62.52**	-113.56***	3.47	-82.27***
	(14.62)	(14.62)	(54.51)	(11.23)	(6.14)	(29.74)	(30.15)	(10.99)	(30.55)
Second	-25.36*	-47.55***	-101.68**	-8.48	5.50	-62.94**	-105.02***	-5.87	-79.86***
Trimester	(13.52)	(13.92)	(51.37)	(10.52)	(5.58)	(27.89)	(27.45)	(11.25)	(27.81)
Third	-35.98**	-77.41***	-141.25*	-13.95	3.60	-85.36**	-147.89***	8.81	-109.55***
Trimester	(17.89)	(18.39)	(71.95)	(14.71)	(7.40)	(39.01)	(38.89)	(14.72)	(39.28)
R²	0.07	0.08	0.08	0.05	0.06	0.05	0.06	0.06	0.06
Observations	17,603	16,866	215,815	3,983,943	12,347,288	4,199,758	12,563,103	16,331,231	16,547,046
Mean DV	3390.54	3351.63	3388.45	3434.24	3483.25	3431.86	3481.59	3471.24	3470.14

Notes: all regressions include county characteristics (real per capita income, percentage whites, percentage blacks, percentage male, percentage manufacturing, and real wages), dummied for mother's characteristics (race, education, age, marital status, Hispanic origin, birth order, and cigarette smoking), dummies for father's characteristics (age, Hispanic origin, and race), and dummies for missing indicator of mother's and father's characteristics. All regressions also include county, month of gestation, year of birth, and mother's country of origin fixed effects. Standard errors are reported in parentheses.
* $p < 0.1$
** $p < 0.05$

231

Table 3. *Selective Fertility: Ramadan and Mothers' Characteristics*

	Outcome: Education	Outcome: Marital Status
	(1)	(2)
Exposure dummy		
	-0.73	-0.25
	(1.79)	(1.58)
R^2	0.29	0.01
Daylight Hours of Exposure		
	-0.0045	0.0001
	(0.0046)	(0.0002)
R^2	0.29	0.001
Daylight Hours of Exposure by Trimester		
First Trimester	-0.002	-0.001
	(0.005)	(0.005)
Second Trimester	-0.002	-0.003
	(0.005)	(0.004)
Third Trimester	-0.006	0.003
	(0.005)	(0.004)
R^2	0.29	0.001
Observations	15,044,225	15,051,455

Notes. Robust standard errors, clustered at county level, are reported in parentheses. Individual and county covariates are explained in the text.
∗ $p < 0.1$
∗∗ $p < 0.05$

References

Almond, D., & Currie, J. (2011). Killing me softly: The fetal origins hypothesis. *Journal of Economic Perspectives*, 25(3), 153–172. doi. 10.1257/jep.25.3.153

Almond, D., & Mazumder, B. (2011). Health capital and the prenatal environment: the effect of Ramadan observance during pregnancy. *American Economic Journal: Applied Economics*, 3(4), 56–85. doi. 10.1257/app.3.4.56

Almond, D., Mazumder, B., & Van Ewijk, R. (2014). In utero Ramadan exposure and children's academic performance. *The Economic Journal*, 125(589), 1501–1533. doi. 10.1111/ecoj.12168

Behrman, J.R., & Rosenzweig, M.R. (2004). Returns to birthweight. *Review of Economics and Statistics*, 86(2), 586–601. 10.1162/003465304323031139

Haeck, C., & Lefebvre, P. (2016). A simple recipe: The effect of a prenatal nutrition program on child health at birth. *Labour Economics*, 41, 77–89. doi. 10.1016/j.labeco.2016.05.003

Hoynes, H., Miller, D., & Simon, D. (2015). Income, the earned income tax credit, and infant health. *American Economic Journal: Economic Policy*, 7(1), 172–211. doi. 10.1257/pol.20120179

Hoynes, H., Page, M., & Stevens, A.H. (2011). Can targeted transfers improve birth outcomes?. Evidence from the introduction of the WIC program. *Journal of Public Economics*, 95(7–8), 813–827. doi. 10.1016/j.jpubeco.2010.12.006

Joosoph, J., Abu, J., & Yu, S.L. (2004). A survey of fasting during pregnancy. *Singapore Medical Journal*, 45(12), 583–586.

Jürges, H. (2015). Ramadan fasting, sex-ratio at birth, and birth weight: No effects on Muslim infants born in Germany. *Economics Letters*, 137, 13–16. doi. 10.1016/j.econlet.2015.10.015

Majid, M.F. (2015). The persistent effects of in utero nutrition shocks over the life cycle: Evidence from Ramadan fasting. *Journal of Development Economics*, 117, 48–57. doi. 10.1016/j.jdeveco.2015.06.006

Mubeen, S.M., Mansoor, S., Hussain, A., & Qadir, S. (2012). Perceptions and practices of fasting in Ramadan during pregnancy in Pakistan. *Iranian Journal of Nursing and Midwifery Research*, 17(7), 467-471.

Myrskylä, M. (2010). The relative effects of shocks in early-and later-life conditions on mortality. *Population and Development Review*, 36(4), 803–829. doi. 10.1111/j.1728-4457.2010.00358.x

NoghaniBehambari, H., Noghani, F., & Tavassoli, N. (2020a). Early life income shocks and old-age cause-specific mortality. *Economic Analysis*, 53(2), 1–19.

NoghaniBehambari, H., Noghani, F., & Tavassoli, N. (2020b). Child support enforcement and child mortality. *Applied Economics Letters*, 1–12. doi. 10.1080/13504851.2020.1869157

Robinson, T., & Raisler, J. (2005). D. "Each one is a doctor for herself": Ramadan fasting among pregnant Muslim women in the United States. *Ethnicity and Disease*, 15(1 SUPPL. 1).

Savitri, A.I., Yadegari, N., Bakker, J., Van Ewijk, R.J.G., Grobbee, D.E., Painter, R.C., Uiterwaal, C.S.P.M., & Roseboom, T.J. (2014). Ramadan fasting and newborn's birth weight in pregnant Muslim women in the Netherlands. *British Journal of Nutrition*, 112(9), 1503–1509. doi. 10.1017/S0007114514002219

Sorensen, H.T., Sabroe, S., Rothman, K.J., Gillman, M., Steffensen, F.H., Fischer, P., & Serensen, T.I.A. (1999). Birth weight and length as predictors for adult height. *American Journal of Epidemiology*, 149(8), 726–729. doi. 10.1093/oxfordjournals.aje.a009881

Tavassoli, N., Noghanibehambari, H., Noghani, F., & Toranji, M. (2020). Upswing in Industrial Activity and Infant Mortality during Late 19th Century US. *Journal of Environments*, 6(1), 1–13. doi. 10.20448/journal.505.2020.61.1.13

Wu, G., Bazer, F.W., Cudd, T.A., Meininger, C.J., & Spencer, T.E. (2004). Maternal nutrition and fetal development. *The Journal of Nutrition*, 134(9), 2169–2172. doi. 10.1093/jn/134.9.2169

Journal of Economic and Social Thought