Can Food Safety Shortfalls Disrupt 'Ag for Nutrition' Gains? Evidence from Eid al-Adha

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Abstract

The international health community has recently stressed the need to raise consumption levels of animal-source foods in developing countries. Development programs based on so-called 'agriculture for nutrition' strategies emphasize the importance of smallholder livestock production to achieve these goals. While much of the literature has highlighted the high nutritional potential of such foods, little attention has been paid to infrastructural deficiencies for handling and processing animal-source foods, particularly meat. Such shortfalls in food safety have the potential to counteract some health gains, especially if renewed international efforts to increase animal consumption are not combined with improved processing capacity. The spike in meat consumption among Muslims worldwide on Eid al-Adha provides a natural experiment to test the extent to which such food safety concerns are justified. Meat processing on this holiday often exceeds the capacity of formal slaughter and processing infrastructure, and thus provides an excellent opportunity to observe the implications of a rapid intensification of meat production and consumption across several countries. Using Demographic and Health Survey (DHS) data from countries in Africa and Asia, we estimate the impact of this holiday on the incidence of diarrheal illness among children. Eid al-Adha provides a plausibly exogenous source of variation in home or informally sourced meat consumption among Muslims, a natural comparison group (Non-Muslims) and independence from seasonal influences (the holiday follows the lunar Islamic calendar). We find that relative to non-Muslims, diarrhea morbidity increases for Muslim children following Eid al-Adha by between 18 and 24 percent. No such similar increase is found on Eid al-Fitr, a similarly important Muslim holiday without home slaughter. These findings reinforce the importance of food safety concerns in livestock sector interventions.

Keywords: Food safety; Nutrition

JEL Classification: I15

I. Introduction

The World Health Organization (2015) estimates that foodborne hazards cause 550 million cases of diarrhea worldwide. These illnesses result in 230,000 annual deaths, with children under five bearing approximately 40 percent of the global disease burden from foodborne illness. Children in developing countries bear a disproportionate risk of both contracting and dying from a foodborne illness.

Despite the danger of illness-causing foods, it is clear that the nutritional intake of many children is inadequate. Black et al (2011) estimate that approximately one quarter of children worldwide, and nearly 40 percent of African children, are stunted. The nutritional deficits suffered by children cause enormous losses in physical wellbeing, cognition, and economic productivity later in life (Hoddinott et al 2013). Remedying these deficits is now a key component of major development initiatives (e.g. USAID's Feed the Future (FTF) program).

Renewed attention to the importance of nutrition has focused policy on increasing animal-source food consumption, which is a key element of a high quality diet (Neumann et al 2014). The agricultural sector has been an important focus of these efforts due to the interdependence of food production, nutrition and health outcomes (DFID 2014). For animal-source foods, in particular, interventions aimed at increasing animal production and animal product availability, especially among smallholders in rural markets, provide a seemingly clear opportunity to increase intake and access to these products for potentially food insecure populations.

While the potential benefits of animal-source food consumption are clear, little is known about potential health complications that may arise from the growth of such food sources in resource-poor settings. Increased consumption of animal source foods may increase the risk of disease due to foodborne pathogens when not properly handled and prepared. Such pathogens can result in not only acute illness, but also negative nutritional outcomes. While studies on the effects of diarrheal illness on childhood stunting have produced varied results on the degree to which lifelong stunting can be attributed to diarrheal episodes, it is evident that diarrheal episodes impact a child's odds of being stunted (Checkley, 2008). Micronutrient deficiency and undernourishment impact immune function; which can lead to a greater susceptibility to intestinal infection and impaired nutrient absorption, causing a cyclical effect of undernourishment and chronic diarrheal illness. Moreover, at risk populations for foodborne bacterial illness and malnutrition overlap (i.e. children under the age of 5, pregnant women, the elderly, and the immune compromised), creating a larger gap for the most vulnerable populations.

Despite the known potential dangers, there has been relatively little study of food safety risks associated with home livestock production, particularly in the context of so-called 'agriculture for nutrition' programs. Much of the literature that has examined such risks have focused on issues ancillary to concerns associated with slaughter and consumption, such as zoonotic transmission pathways. While these areas are important, consumptive risks of foodborne illness from home slaughter or local, informal sources, represent a direct, and potentially avertable, food safety threat.

The spike in meat consumption among Muslims worldwide on Eid al-Adha provides a natural experiment to test the extent to which such food safety concerns are justified. Meat processing on this holiday often exceeds the capacity of formal slaughter and processing infrastructure, frequently occurring at home, and thus provides an excellent opportunity to observe the implications of a rapid intensification of localized meat production and consumption across several countries. Using Demographic and Health Survey (DHS) data from countries in Africa and Asia, we estimate the impact of meat consumption during this holiday on the incidence of diarrheal illness among children. Eid al-Adha provides a plausibly exogenous source of variation in meat consumption among Muslims, a natural comparison group (Non-Muslims) and independence from seasonal influences (the holiday follows the lunar Islamic calendar).

We find that relative to non-Muslims, diarrhea morbidity increases for Muslim children following Eid al-Adha. The effects are large in magnitude, and robust to several different specifications. No similar increase is found following Eid al-Fitr, a different Muslim holiday not associated with home slaughter. While we examine several issues related to the interpretation of these results in the discussion section, the analysis provides evidence that promotion of animal-source food consumption via efforts targeted at own or local production carry non-trivial food safety risks. These risks likely exceed those that arise 'naturally' (i.e. from increased meat consumption driven by general income growth and consumer demand), since smallholder-producer interventions do not benefit from economies of scale that make some food safety investments attractive.

II. Background and Motivation

II.A. Eid al-Adha

The holiday of Eid al Adha, which celebrates the prophet Ibrahim's devotion to God via the story of the aborted sacrifice of his son, is celebrated by Muslims worldwide. The holiday marks the climax of the Hajj pilgrimage to Mecca, and occurs about ten weeks after Eid al-Fitr, the festival marking the end of Ramadan. Eid al-Adha is often referred to as "the festival of sacrifice" in

commemoration of Prophet Ibrahim's willingness to sacrifice his son in obedience to God. In commemoration of the ram slaughtered in Abraham's son's stead, it is traditional for observers to consume meat, usually sheep or goats. Per the traditions of the ceremony, the meat is divided into three parts: a part each for one's family; relatives, friends, and neighbors; and the poor and needy.

Red meat consumption usually spikes for Muslims during this holiday. For example, Ozertan, Saghain, and Tekguc (2012) note that nearly 40 percent of all small ruminants slaughtered in Turkey are butchered during the week of Eid al-Adha. Davies (2006) estimates that nearly 2 million animals are sacrificed during the festival in Saudi Arabia, alone. As a result, in many countries, a large portion of the meat consumed on this holiday is slaughtered and handled in informal facilities and private residences outside of the formal slaughterhouse system (Leblebicioglu et al 2015).

While exact figures are unknown, anecdotal evidence suggests that the degree of slaughter occurring at home is high. Several factors contribute to the propensity for home or informal slaughter. For one, licensed slaughterhouses can become overwhelmed, causing celebrants to seek alternatives.[1] Performing slaughter at or near one's home can also be a source of pride and signal of wealth, and facilitate charitable giving. Finally, according to the rules of sacrifice, many believe the butcher should be a practicing Muslim, and the slaughter must be done in accordance with Islamic custom (i.e. follow Halal guidelines). Thus, in instances where the religious background of the butcher in the slaughter house is uncertain, especially in non-Muslim majority or secular countries, many resort to slaughtering at home or with a known individual at an unregulated facility.[2]

While observance of the sacrifice is by no means universal among Muslims, it is widespread. Those unfamiliar with the holiday, or disinclined to observe its traditional rituals, can often be taken aback at the degree of informal and public butchering.[3] One Pakistani blogger described the scene as "Carcasses everywhere, blood flowing on the dirty streets in a foul crimson color". Though the description may not be typical, it is clear that the large degree of informal meat processing, often occurring in locations without access to generally used infrastructure, carries the potential for spread of pathogens.[4]

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[1] In the United Arab Emirates (UAE), where officials have attempted, with varying degrees of success, to crack down on slaughter outside official facilities, newspaper reports suggest demand exceeds capacity (e.g. Abdul Khader 2009)
[2] See, for example, Fausset (2007).
[3] See, for example, Kingsley (2014), Cabe (2013) or Loughnan (2012)
[4] See, for example, Xiao et al (2015)

II.B 'Agriculture for Nutrition' and Animal Source Foods

Much of the focus on increasing home livestock production in order to improve human nutrition via animal-source food consumption relies on the existence of non-separability in rural markets in developing countries (see, for example, Azzari et al 2014). In these models, high transaction costs in food markets link household production and consumption decisions, especially for more perishable animal sourced foods like meat and milk. Higher livestock productivity then improves human nutrition via a 'direct consumption' channel.[5]

Policies aimed either explicitly or implicitly at increasing subsistence animal consumption, or rapidly scaling up previously limited, informal rural markets, promote an avenue for greater meat consumption that differs in important ways from historical precedent. The general pattern of non-agricultural income growth leading to higher demand for meat consumption entails increasing specialization and scaling up of meat production (FAO 2009). Within this context, concomitant improvements in meat safety and consumption are not unexpected, as consumers become increasingly aware and willing to bear the higher costs of safer food. Further, lumpy food safety investments become more attractive to increasingly large and specialized producers that are able to take advantage of scale economies.[6]

The same logic does not necessarily apply to efforts aimed at directly subsidizing small holder producers. Without the advantage of scale economies and the possible absence of basic complimentary infrastructure, like water and refrigeration, investments in the specialized physical and human capital required for safe meat processing are much less feasible. As a result, historical evidence of the health consequences of greater livestock production, such as those discussed in Randolph et al (2007), may be a poor predictor of the outcomes associated with recent, smallholder based efforts. With little precedent for such developments, there is little empirical guidance on the degree to which food safety concerns, particularly those associated with meat processing, should concern programs aimed at rapidly increasing smallholder livestock production.

[5] The literature describes other channels for livestock production to influence human nutrition, particularly via increases in income or via positive externalities for crop production (e.g. manure, draft power). However, I focus on the 'direct consumption' channel here, as it is the only one for which increases in livestock production, as opposed to other income sources, have a disproportionate impact on animal source food consumption.

[6] Of course, information asymmetries and principle-agent problems complicate market solutions to food safety concerns, especially as distance between consumer and producer increases (Henson 2003). However, better financed government agencies may be more capable of enacting and enforcing regulations to counteract these problems.

The study of Eid al-Adha represents a unique opportunity to bridge that gap. Because so much of the meat consumed on this holiday is handled informally by non-specialized processors, often households themselves, the outcomes on this holiday should be of interest to those worried about the processing risks associated with increased smallholder own-animal consumption. Further, strong norms regarding charity result in widespread sharing of meat with the poor, and ensures that meat consumption occurs among households of all levels of socioeconomic status.

II.C Food Safety and Nutrition

Within the context of recent attention on 'agriculture for nutrition', there has been some limited recognition that increases in animal sourced food consumption beget greater food safety concerns when concomitant increases in processing infrastructure and knowledge are lacking (e.g. Gelli et al (2015)). However, the degree of focus has been limited, and mainly directed at risks from husbandry practices, as opposed to slaughter, or even chronic disease. It is unclear to what extent funding and research priorities reflect potential food safety concerns, given the much greater attention paid to the potential nutritional gains associated with "nutrition-sensitive" agriculture. A recent "Agriculture-Nutrition" call for proposals funded by the Gates Foundation and the UK Department for International Development (DFID) emphasized the importance of measuring the potential nutritional improvement pathway between animal-source food consumption and agricultural improvements, but made no mention of food safety.

Much of the focus on human health concerns associated with increased animal production centers on zoonotic disease. Globally, many zoonotic epidemics are estimated to occur annually warranting the commitment of huge financial and other resources to address. Over the years, the World Health Organization (WHO) and other national and international bodies have discussed various issues bordering on the transmission of zoonotic (as well as food-borne) pathogens from animals to humans. The transmission of these pathogens is usually attributed to the association of domesticated animals (Wolfe et al, 2007) and the manner in which these animals (especially livestock) are handled, slaughtered, and prepared for consumption. Additionally, the recognition of some infectious diseases having wildlife origins highlights the need to better understand types of contacts between wild animals and humans that facilitate disease transmission (Jones et al, 2008; Morens and Fauci, 2013; Johnson et al, 2015). Despite collaborative efforts of the WHO and its partners to assist vulnerable member states, there are still high-risk practices in the transmission of pathogens along the food chain. However, since improper handling by consumers of livestock products often represents the greatest food safety risks

(dos Muchangos et al, 2015), the potential for pathogen contamination from home-sourced consumption could be even larger.

Well publicized emergencies have stirred public health officials to pay closer attention to food safety threats (Chan, 2014). However, these calls rarely center on household level food production and processing. Some recent work has sought to better understand the human nutrition impacts of livestock keeping in rural settings in developing countries from a food safety perspective.

Prendergast and Humphrey (2014), and Dufour et al (2012) review avenues through which fecal contamination of household surfaces and water by livestock could lead to adverse nutritional outcomes in children (e.g. stunting). Based on observations from Ngure et al (2013) that some young children in Zimbabwe living in households with poultry ingest significant quantities of chicken feces and contaminated soil, Headey and Hirvonen (2015) find that keeping poultry indoors increases the risk of stunting in Ethiopian households. Headey et al (2016) likewise find a negative association between child height and the presence of animal feces in Bangladesh and Ethiopia. While these relationships are intriguing, the correlations cannot be considered causal evidence of a negative relationship between livestock keeping and nutritional status. Many of the same factors associated with livestock keeping practices may also influence child nutritional status. Our study provides more plausible causal estimates, as Eid al-Adha provides a natural experiment that enables us to deal with endogeneity concerns.

III. Data

We use Demographic and Health Survey (DHS) data from 9 countries in Africa and Asia: Burkina Faso, Guinea, India, Mali, Mozambique, Niger, Nigeria, Tanzania, and Uganda. These countries were selected from the universe of samples available from the Integrated Demographic and Health Survey project (IPUMS-DHS 2016) because they contain survey data on both Muslim and non-Muslim households interviewed within 14 days of Eid al-Adha. The method of selection implies that these countries are not representative of either the Muslim world or developing country populations generally. However, they represent three important regions for Muslim populations in developing countries: East Africa, West Africa, and South Asia.

The sample of countries (Table 1) is diverse in terms of population (India is by far the most populace, while Guinea is the least), and proportion of the population comprised of Muslims (Niger the highest at .98, while Uganda has only .12). However, they share several key features: high rates of stunting, diarrhea morbidity, and child mortality from diarrhea. The statistics highlight an important phenomenon: many children suffer from both poor nutritional status and basic deficiencies in hygiene

and protection from illness causing pathogens. While animal source foods are an excellent means to combat the former, they also have the potential to exacerbate the latter.

The estimation samples consists of 339,867 self-identified Muslim children under 5 years old, and 347,771 non-Muslim children in the same age range (Table 2). Despite the religious parity in the total sample, religious diversity in the sample varies considerably within each country, in accordance with the population composition. The timing of surveys with respect to Eid appears close to random, with some small differences between Muslims and non-Muslims. Given a fourteen-day exposure period (to match the recall window for diarrhea), we would expect roughly 3.8 percent of the sample to be surveyed within 14 days of the holiday if survey timing was random. Overall, 3.6 percent (4.1 percent for Non-Muslims, 3.3 percent for Muslims)[7] of the sample were surveyed in the 14 day exposure window.

IV. Methodology

Determining the impact of home-sourced meat consumption on health outcomes is complicated by several factors, including the paucity of data on the timing of home-sourced consumption and the confounding of the decision to consume home-sourced meat with other factors that affect health. Factors like income, distance to market, household composition, as well as typically unobserved variables like food safety knowledge, home environment and health status affect both susceptibility to illness and likelihood of consuming home sourced-meat. As a result, isolating the impact of home sourced meat on, for example, diarrhea, is difficult without a source of exogenous variation in home-sourced meat consumption.

Eid al-Adha provides such variation for several reasons: (1) The holiday induces adherents to engage in home-sourced meat consumption, irrespective of other factors; (2) The existence of non-Muslims, who are not induced to consume home-sourced meat, provides a natural control group with which to construct a valid counterfactual; and (3) Because Eid al-Adha follows a lunar calendar, we can disentangle diarrhea resulting from shocks to meat consumption from seasonal factors that also contribute to illness.

To implement this strategy, we use a difference-in-difference specification to estimate variants of the following model:

$$\boldsymbol{Y_{im} = \beta_0 + \beta_1 Eid_{im} + \beta_2 Muslim_{im} + \beta_3 Muslim * Eid_{im} + X'\alpha + \mu_m + e_{im}}$$

[7] Within-region and within-country linear probability estimates did not show significant differences in survey timing by religion.

Where Y_{im} is a dummy variable for whether child i in month m experienced diarrhea in the previous 14 days.[8] The variable $\boldsymbol{Eid_{im}}$ is a dummy for whether Eid al-Adha occurred in the previous 14 days and $\boldsymbol{Muslim_{im}}$ denotes whether the child is Muslim, $\boldsymbol{X}$ is a vector of control variables, and $\boldsymbol{\mu_m}$ month of interview fixed effects. The coefficient $\boldsymbol{\beta_3}$ represents the DID parameter of interest. The control variables include child's age, age of mother, water source and urban/rural status.

Several estimation issues complicate the analysis. First the model above implies a complete pooling of individuals across all surveys and countries, which ignores geographic heterogeneity. As a result, we examine several alternative specifications, focusing on specifying either random or fixed effects at the region level. The latter, 'within' region estimates, rely solely on the differences in the relative Eid diarrhea rates between Muslims and Non-Muslims within a given region of the country.

Similarly, for several reasons, the regression errors are likely to be correlated among individuals within a given geographic area. We therefore estimate cluster-robust standard errors at both the region and country level. Because of the small number of clusters, particularly when specifying the more conservative country level clustering (9 clusters), standard errors are estimated using the wild bootstrap procedure shown to be more reliable in the case of small numbers of clusters (Cameron, Gelbach and Miller 2015).

V. Results

V.A Main Estimates

Pooled model estimates (Table 3) indicate a positive and significant impact of Eid al-Adha on the incidence of diarrhea. The difference in difference (DID) coefficient indicates that relative to non-Muslims, Muslim children are 3.7 percentage points more likely to report the occurrence of diarrhea when Eid al-Adha falls within the 14-day reporting period. That represents a 24 percent increase relative to the mean diarrhea rate (15.3 percent) in the sample. When the standard errors are clustered at the country level (9 groups), the estimate is significant at the 5 percent level using the conventional cluster robust variance calculation, but the p-value doubles to .056 when calculated using the wild bootstrap. When clustering at the region level (81 groups), the conventional clustered error remains significant at the 5 percent level, but the p-value decreases to less than .01 using the wild bootstrap.

Unobserved local heterogeneity has the potential to bias impact estimates, so we also examine regional random and fixed effect models (Table 4). Relative to the pooled model estimates, the

[8] Our focus on diarrhea as an outcome variable is driven by the fact that it represents a serious mortality risk to children and is the most common foodborne disease and complication from consuming contaminated meat products (WHO 2015).

estimated impact of Eid al-Adha is reduced by about 25 percent, but remains positive and significant. Using the fixed effect estimate, the rise in diarrhea attributable to Eid al-Adha is approximately 18 percent, with a bootstrapped p-value below .036. Thus, under a variety of specifications, we find Muslim children report a large and statistically significant increase in diarrhea as a result of Eid al-Adha.

V.B Placebo Estimates

The main estimates indicate that Muslim children report relatively higher rates of diarrhea following Eid al-Adha. However, two concerns remain. For one, it is possible that some element of the holiday is biasing the estimates in an unforeseen manner, and causing us to observe spurious positive results. For another, even if the estimates indeed reflect higher risk of diarrhea among Muslim children following Eid, there remains no direct evidence tying that risk to livestock slaughter or handling practices. Indeed, it is possible that other elements associated with the holiday, such as travel or other changes to daily routine or non-meat consumption, are the primary cause of increased illness. At the very least, these other factors might partially contribute to the estimated effect.

To determine the validity of these concerns, we estimate 'placebo' regressions using the Muslim holiday of Eid al-Fitr. Eid al-Fitr is an important Islamic holiday celebrated worldwide to mark the end of Ramadan (i.e. the month of fasting and abstinence). Similar to Eid al-Adha, Eid al-Fitr (alternatively refered to as "Small Eid, Sweet Festival, Feast of fasting etc) follows a lunar Islamic calendar and varies annually and geographically. The holiday can last up to four days, and observers are typically encouraged to give to charity, celebrate with family and neighbors, and forgive offenders. The holiday is often marked by large, festive meals that feature rich, sweet foods (Ghosh 2016; Zubaid et al 2006).

Using the same procedure and specification in the Eid al-Adha regressions, we define a variable to represent occurrence of Eid al-Fitr within the 14-day exposure period prior to the survey interview date. We then estimate the DID parameters using the same specifications as before, but substituting Eid al-Fitr exposure for Eid al-Adha. If the estimated DID coefficients from the placebo regressions are positive and of similar magnitudes to the main estimates, Muslim children would appear to also be at higher risk for diarrhea due to Eid al-Fitr. Such a result would reinforce concerns that the previous estimates are influenced by factors other than meat processing and handling on Eid al-Adha. On the other hand, null results would suggest that the main results are not driven by factors generic to important Muslim holidays (e.g. communal meals, shifts in food consumption, spurious reporting bias, etc).

As in the main results, we estimate two sets of regressions (Tables 5 and 6). In all estimates, the DID coefficient is close to zero and statistically insignificant (p-values>.8). The coefficient estimates range from -.003 to .008, and are all significantly different from the Eid al-Adha coefficient estimates (ranging from .028 to .037). We find no evidence that Eid al-Fitr leads to a similar increase in diarrhea morbidity among Muslim children.

VI. Discussion

The results demonstrate a clear elevated risk of diarrhea associated with the occurrence of Eid al-Adha. The effect is robust to several different specifications of the estimating equation and error structure. Given the strong tradition of home slaughter and direct carcass handling within the household on this holiday, the increased pathogen risk associated with these practices is likely an important driver of the rise in illness incidence. While it is known that higher intensities of home-sourced animal consumption increase food safety risks, our regression estimates suggest the actual impact on morbidity is significant in magnitude.

The findings have implications for development strategies that emphasize household animal production as a means to increase animal source food consumption and improve nutrition. Programs that aim to strongly increase the level of meat production and consumption in diverse communities without attention to food safety infrastructure run a real risk of problems from food-borne illness. More research is needed on cost-effective solutions that can mitigate these risks while still achieving the desired nutritional goals.

A key weakness of the analysis is our inability to directly observe the source and frequency of meat consumption of individuals in our sample. Given the lack of precise data on the proportion of Muslims who slaughter ruminants at home on Eid, we are unable use the results to calibrate a more general estimate of the illness risk associated with marginal increases in home-sourced animal consumption. While we believe the results suggest clear evidence that the food safety risk of increased home slaughter is non-trivial, the potential nutritional gains from a net increase in animal-sourced foods are also obvious. Therefore, despite the results here, the degree to which efforts to increase such consumption should account for food safety concerns remains unknown. However, the evidence here suggests it is non-zero.

The lack of direct data on slaughter, food preparation and consumption also obscures the mechanism underlying the increased child diarrhea risk from Eid al-Adha. However, our placebo estimates using another major Islamic holiday, Eid al-Fitr, suggest that the results do not stem from

elements associated with general holiday observance, such as travel, increased social contact, generic dietary variation, or other changes to daily routine. Thus, animal handling and processing remains a likely explanation for the observed increase.

Still, the nature of the risk posed by home-sourced meat consumption is somewhat ambiguous. One hypothesis is that direct consumption of inexpertly processed meat drives the higher relative rates of diarrhea. We doubt the primacy of this 'direct' hypothesis for several reasons. First, poor meat handling practices are common across several outlets in developing countries, and thus household preparations often involve safe cooking methods. This is especially true for mutton, whose pathogen transmission risk is often mitigated by thorough cooking (Kijlstra and Jongert 2009; Stutmoller 1997).[9] Second, our sample of children under five is unlikely to eat significant quantities of meat. In the few recent DHS surveys that include data on frequency of food group consumption for children, we do not find a relative increase in meat consumption for Muslim children under 5 associated with the occurrence of Eid al Adha.[10]

Instead, we speculate that the results are strongly driven by cross-contamination of microbial pathogens due to home slaughter and carcass handling on Eid Al-Adha. Cross-contamination occurs when raw animal flesh comes in contact with surfaces or utensils used in food preparation.[11] Adesokan and Raji (2014) note that contamination from raw meat is an important source of food-borne illness in several countries, and knowledge in Nigeria, for example, of practices required to reduce this risk was relatively low.[12] Home processing of ruminants is less likely to involve the use of even rudimentary specialized equipment, such as separate slabs or washing stations. Such slaughter increases the risk that other household items used in food preparation come in contact with raw flesh or blood, either directly (e.g. via splatter), or indirectly (e.g. spread by the household member who handles the carcass).[13] As a result, food consumed by young children may be at greater risk of contamination during or after Eid al-Adha.[14]

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[9] Indeed, many traditional Eid dishes in the sample countries involve roasting at high heat or stews involving boiled lamb, both of which are 'low-risk' preparations.

[10] The findings must be taken with a great deal of caution, as the small number of surveys and shorter recall period (7 days) severely limits the amount of in country variation between Muslims and non-Muslims with respect to the occurrence of Eid.

[11] Adeyemo et al (2009) and Okoli et al (2006) note the possibility of cross-contamination from dressing and dragging carcasses on the bare floor together with entrails as well as transporting by unconventional means

[12] In their quiz of meat processing employees, the question associated with cross-contamination was the least correctly answered by both government and private employees.

[13] Such indirect transmission may also occur even if the actual slaughter is done outside the home, but the carcass is handled by a household member.

[14] In Nigeria, a medical official has reported that many people are rushed to hospitals during Eid al-Adha with diarrhea caused by eating improperly prepared meat (Edeh 2013).

A more conclusive establishment of the mechanism behind the result would yield better information about the general risks reflected in the increase in diarrhea associated with Eid al-Adha. Cross-contamination represents a general food safety risk from home-sourced meat consumption,[15] and the results here may portend similar issues as resources are increasingly dedicated to promoting animal sourced foods via agricultural projects. In Ethiopia, for example, Dewe et al (2013) note that while slaughter of ruminants usually occurs at home and cross-contamination risk is high, pathogen exposure is limited simply by the sheer rarity of consumption. An increase in the frequency of home sourced meat consumption would theoretically increase risk of illness, and the evidence from Eid al-Adha suggests that the size of the increase is meaningful.

VII. Conclusion

Increased recognition of the role of nutrition in human capital formation and economic development has spurred greater levels of interest in and funding for interventions aimed at increasing nutritional status in developing countries. One component of these efforts has been 'Agriculture for Nutrition' programs, which aim to use agriculture as a solution to nutrition and health challenges among poor households, especially smallholder farmers. Among other aims, these programs often seek to promote the consumption of animal-source foods through interventions aimed at increasing local livestock production. However, given the large, existing deficits in the processing and handling infrastructure of such foods, large increases in local slaughter may entail significant food safety risks. Our paper seeks to quantify these potential health risks by analyzing a natural experiment that provides a similarly large increase in locally slaughtered and consumed ruminants.

In this paper, we estimate the impact of Eid al-Adha, an Islamic holiday characterized by extensive slaughter of small and large ruminants, on the occurrence of diarrheal disease among children under five years. We find that diarrhea morbidity increases within 14 days of Eid al-Adha for Muslim children relative to non-Muslim children by between 18 and 24 percent. Our placebo analysis of Eid al-Fitr, another major Islamic festival not characterized by extensive home slaughter of animals, suggest that our results are unlikely to be driven by generic increases in diarrhea risk associated with holidays, and hence more likely to stem specifically from animal processing practices on Eid al-Adha.

Taken as a whole, our estimates indicate that potential health risks due to increased local livestock processing are non-trivial. While improving access to animal source foods must remain a crucial

[15] Ehiri et al (2001) likewise note the key role played by cross-contamination from other sources in the safety of complementary foods fed to children in Eastern Nigeria.

component of efforts to improve nutritional status across the globe, a more careful risk assessment of strategies that seek to do so via household livestock production efforts is needed.

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Table 1: Country Summary Statistics

Country	Population (thousands)[1]	GDP per capita (2011 PPP $)[2]	Human Development Index Rank[2]	Percent Muslim[3]	Stunting prevalence (%)[4]	Diarrhea Rate (%) within 14 days (children under 5 years)[5]	Mortality (%) due to diarrhea (children under 5 years)[6]
Burkina Faso	18,106	1,582	183	58.9	32.9	17.6	8
Guinea	12,609	1,213	182	84.2	31.3	16.5	8
India	1,311,051	5,238	130	14.6	38.7	12.4	10
Mali	17,600	1,589	179	92.4	38.5	16.3	9
Mozambique	27,978	1,070	180	22.8	43.1	13.0	9
Niger	19,899	887	188	98.3	43.0	21.2	11
Nigeria	182,202	5,423	152	47.9	32.9	12.7	10
Tanzania	53,470	1,718	151	29.9	34.7	13.7	8
Uganda	39,032	1,368	163	12.0	34.2	24.4	8

[1] Source: United Nations, Department of Economic and Social Affairs, Population Division. World Population Prospects: The 2015 Revision.
[2] Source: United Nations Development Programme (UNDP) Human Development Report 2015: Work for Human Development.
[3] Source: Pew Research Center's Forum on Religion & Public Life. The Future of the Global Muslim Population: Projections for 2010-2030
[4] Source: UNICEF-WHO-The World Bank Group Joint Child Malnutrition Estimates: Levels and Trends (2015 Edition)
[5] Source: Authors' computation from Demographic and Health Surveys (1987-2013)
[6] Source: WHO and Maternal and Child Epidemiology Estimation Group (MCEE) estimates 2015

Table 2: Sample Size by Religion

	Non-Muslim	*Muslim*
Guinea	6,340	52,581
India	113,860	20,205
Mali	3,709	44,711
Mozambique	52,753	14,895
Niger	484	44,209
Nigeria	54,825	86,078
Uganda	47,313	7,229
Tanzania	34,146	20,494
Burkina Faso	34,341	49,465

Source: Authors' calculation from Demographic and Health Surveys (1987-2013)

Table 3: Results from the Pooled Model

Impact of Eid al-Adha on Diarrhea Rates of Children under Five		
	Diarrhea within 14 days	
Muslim X Eid within 14 days (DID)	.037	.037
Cluster Robust SE	[.0016]**	[.015]**
Wild Bootstrap p-value	.056	.005
Eid within 14 Days	-.005	-.005
Cluster Robust SE	[.008]	[.581]
Wild Bootstrap p-value	.571	.664
Muslim	.031	.031
Cluster Robust SE	[.015]*	[.011]***
Wild Bootstrap p-value	.075	.011
N	682,279	682,279
Region Random Effects	No	No
Region Fixed Effects	No	No
Cluster Level	Country	Region

Dependent variable in all regressions is dummy variable for whether child had diarrhea within 14 days of interview. All regressions control for month of interview, child's age, age of mother, and urban/rural status. Additional controls and standard error calculations noted in the table. * $p<0.1$ ** $p<0.05$; *** $p<0.01$.

Table 4: Results from Random and Fixed Effect Models

Impact of Eid al-Adha on Diarrhea Rates of Children under Five		
	Diarrhea within 14 days	
Muslim X Eid within 14 days (DID)	.029	.028
Cluster Robust SE	[.010]***	[.010]**
Wild Bootstrap p-value	---	.036
N	682,279	682,279
Region Random Effects	Yes	No
Region Fixed Effects	No	Yes

Estimate for difference-in-difference variable is only coefficient shown. Dependent variable in all regressions is dummy variable for whether child had diarrhea within 14 days of interview. All regressions control for Eid occurring within 14 days of the interview, Muslim, month of interview, child's age, age of mother, and urban/rural status. Additional controls and standard error calculations noted in the table. * $p<0.1$ ** $p<0.05$; *** $p<0.01$.

Table 5: Placebo Results from Pooled Model

Impact of Eid al-Fitr on Diarrhea Rates of Children under Five		
	Diarrhea within 14 days	
Muslim X Eid al-Fitr within 14 days (DID)	-0.003	-0.003
Cluster Robust SE	(0.016)	(0.010)
Wild Bootstrap p-value	0.869	0.808
Eid al-Fitr within 14 days	-0.001	-0.001
Cluster Robust SE	(0.011)	(0.006)
Wild Bootstrap p-value	0.976	0.859
Muslim	0.032	0.032
Cluster Robust SE	(0.016)*	(0.011)***
Wild Bootstrap p-value	0.059	0.011
N	682,268	682,268
Region Random Effects	No	No
Region Fixed Effects	No	No
Cluster Level	Country	Region

Standard errors clustered at respective country and region levels in parentheses. Dependent variable is a dummy for the occurrence of diarrhea within 14 days of Eid al-Fitr celebration. * $p<0.1$ ** $p<0.05$; *** $p<0.01$.

Table 6: Placebo Results from Random and Fixed Effect Models

Impact of Eid al-Fitr on Diarrhea Rates of Children under Five		
	Diarrhea within 14 days	
Muslim X Eid al-Fitr within 14 days (DID)	0.008	0.008
Cluster Robust SE	(0.014)	(0.014)
Wild Bootstrap p-value	----	0.896
N	682,268	682,268
Region Random Effects	Yes	No
Region Fixed Effects	No	Yes

Standard errors clustered at respective country and region levels in parentheses. Dependent variable is a dummy for the occurrence of diarrhea within 14 days of Eid al-Fitr celebration. * $p<0.1$ ** $p<0.05$; *** $p<0.01$.