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Typhoons and Lower Birth Weight in the Philippines

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Abstract: Do typhoons impact birth weights of infants exposed to a typhoon while in utero? This research exploits the exogeneity and randomness of typhoons in the Philippines to estimate the impact of typhoon exposure as determined by wind speed on birth weights. Using four waves of the Demographic and Health Survey (DHS) data from the Philippines combined with temperature, precipitation, and rainfall data from the Philippines, I can empirically estimate the impact of a 1 m/s increase in wind speed on birth weights. I find that for certain subgroups of the population, specifically children born to mothers with primary education or less, typhoon exposure in the year of birth and more specifically the quarter of birth, has a negative and statistically significant effect on birth weights. Since birth weights are common indicators of overall infant health as well as predictors of later life outcomes, these findings are important for policymakers. Policy implications of this study include shifting the focus of campaigns directed to focus on the importance of health and nutrition in the later stages of pregnancy, and also focusing on the needs of pregnant women in post-typhoon aid and relief efforts.

1. Introduction

Natural disasters are known to be extremely devastating, causing much damage for those exposed, even in countries with relatively sound emergency preparedness systems. In general, researchers have had traction in estimating losses due to physical damage. However, certain types of losses—intangible, indirect damages—are harder to quantify. Most of these losses that are difficult to quantify are the long-term impacts of these initial, shorter-term losses due to natural disasters. More specifically, it is difficult to quantify the indirect impact of the instantaneous losses of physical damage on the time period(s) following a natural disaster. The extent to which households are impacted by natural disasters naturally varies; meaning the time it takes to recover from such a devastating loss will vary as well. This is a concern for any country, but especially for those in the developing world where wealth and welfare may already be at low levels, as a natural disaster may be costing more than our standard measures of losses allows us to estimate.

The Philippines experiences its share of natural disasters on a yearly basis—on average experiencing roughly 10 typhoons/tropical cyclones that are ranging mild to severe (Anttila-Hughes & Hsiang, 2013). Considering the recent predictions on climate change that suggest the frequency of weather related natural disasters will likely increase, addressing the complete impact of typhoons on households beyond the physical damages is essential (IPCC, 2007). We know that expenditures and consumption are affected negatively post-natural disaster (Anttila-Hughes & Hsiang 2013, Morales 2013). With this in mind, it is possible that there are indirect longer-term effects of these natural disasters through its impact on household's economic stability or the stress brought on by the event. This research seeks to determine if these indirect, potentially longer-term impacts of typhoons impact fetal health outcomes, which may impact human capital outcomes in the long run.

More specifically, this research seeks to answer the question: *does typhoon exposure impact birth weights?* This could be due to in utero exposure, or due to economic impacts on households, which may impact the health of the fetus. Although, it is difficult to determine the mechanism in which typhoons may impact birth weights, there are a few likely mechanisms in which typhoons impact birth weights. Potentially, the shock of the typhoon may cause immediate stress and impact pregnancies (such as cause preterm births), or the longer-term stresses brought upon by typhoons may cause long lasting stress throughout a pregnancy, impacting health of the fetus. Alternatively or additionally, typhoons or hurricanes can have a severe impact on nutrition of the exposed population, which can in turn impact health outcomes (del Ninno and Dorosh 2002; O'Donnel, Bacos & Bennish 2002). The mechanism through which this occurs is through interruption in household food consumption, whether it is through lack of availability or damage and destruction disrupting the supply (Paul et al., 2012). These impacts on food consumption are especially devastating for poorer households (del Ninno and Dorosh 2002; O'Donnel, Bacos & Bennish 2002). Disease prevalence and contamination as well as damage to health infrastructure may also occur as a result of natural disasters, and this can impact health and health care availability (Paul et al, 2012). Since health and nutrition is essential throughout the whole pregnancy, it is important that expectant mothers are able to maintain a balanced diet and are in healthy environments. Given the David Barker's fetal origins hypothesis and the recent findings on the negative impacts of shocks while in utero (Currie & Almond, 2011), this research will seek to add to the existing literature and determine whether possible in utero exposure to typhoons may results in negative impacts on birth weights. The mechanism, economic instability or stress, will be harder to determine, however given the implications of low birth weights on later life outcomes, this is important to assess. This study adds to the growing body of literature in this field investigating the impacts of in utero exposure on birth weight, and brings analysis of a country hit frequently by typhoons, which has not been analyzed in depth yet.

Using a combination of four waves of Demographic and Health Survey (DHS) data (1993, 1998, 2003, 2008), as well as data on typhoons (years 1989-2008) constructed from LICRICE (Limited Information Cyclone Restoration and Integration for Climate Economics) model used in and Hsiang (2010) constructed by Hsiang, I use wind speed as a measure of storm intensity, and estimate the impact of these storms on children born to mothers who were pregnant during the time of exposure. I find that in the year a typhoon hits, and more specifically if exposure occurs in the quarter of the year that the child is born, there are negative and statistically significant impacts of typhoons on birth weight for a portion of the population. I also find an interesting gender difference in impacts of in utero typhoon exposure birth weight that needs to be further investigated.

2. Literature Review

i. In Utero Exposure and the Fetal Origins Hypothesis

Human capital theory tells us that increasing human capital, such as increasing a person's stock of knowledge or improving one's ability will likely increase their productivity in the workforce, allowing for potentially better later life outcomes in aspects such as earnings

(Grossman 2000). As part of this growing field of theory and empirics relating to human capital, researchers have begun trying to determine and investigate the inputs and outputs of human capital. The epidemiological literature is initially responsible for expanding this research into investigating how in-utero and early life exposures and conditions, may affect human capital. David Barker (1995) formalized the idea of the fetal origins hypothesis through his research on in-utero nutrition's impact on fetal growth and coronary heart disease. This idea has been expanded upon in the economics field, as economists are interested in the fetal origins hypothesis for many reasons but primarily for it's implications for human capital. Currie and Almond's (2011) fetal origins hypothesis paper gives a good review of the fetal origins idea and discusses the economics research that has begun to further investigate in-utero exposure to different types of shocks. As explained by Currie and Almond (2011), the fetal origins hypothesis recognizes that negative in-utero exposure can impact fetuses, and have adverse health effects that may remain concealed for many years. It also recognizes that adult health behavior and decisions (smoking, exercise, diet, and other environmental exposures) may indeed impact the fetus, (Currie & Almond, 2011). Other research has shown that health at birth may be impacted directly by prenatal inputs, which relates to parental behaviors and decisions (Rosales, 2013).

ii. Importance of Birth Weight

From the literature, we know birth weight has been the most widely used and accepted measure of infant health. Birth weight is also associated with later life outcomes, such education, IQ and earnings, as well as health outcomes such as height and BMI. (Black et al. 2007). Lower birth weight in particular may be an indicator for health and developmental challenges (Simeonova 2011). Other research has shown that increasing birth weight increases adult schooling outcomes and suggests shifting the birth weight distribution in developing countries to that of the birth weight distribution in the US may reduce world earnings inequality (Rosenzweig & Behrman 2004). Currie & Hyson (1999) study births in Britain and find that higher birth weights are associated with higher levels of educational attainment, as well as self-reported health status and employment. Mancini and Yang (2009) find negative impacts of low birth weight on educational attainment. This makes researching the factors that influence birth weight even more important to address, and makes birth weight even more important to monitor. With this in mind, this research seeks to understand whether a pregnant mother's exposure to typhoons effects birth weight, an important indicator of later life outcomes. There are a few recent studies that have looked at the impact of stressful situations such as typhoons and other natural disasters on birth weights, but this research will add to the growing body of literature by examining the impact of typhoons on birth weight in the Philippines, a country impacted heavily by typhoons on a regular basis.

2.1 *Natural Disasters, Stress and Birth Weight*

Xiong et al. (2008), Callaghan (2007) and Simeonova (2011), all investigate the impact of maternal stress due to typhoons (Simenova also includes other types of natural disasters in addition to typhoons in her analysis) on birth weights and find negative impacts of hurricanes on birth weight. In all of these studies, the authors are mainly examining stress estimate the impact of Hurricane Katrina on birth weights of newborns whose mother was exposed to Hurricane Katrina. Xiong et al. (2008) estimate the impact of high hurricane experience, post-traumatic stress syndrome (PTSD), and depression on pregnancy outcomes. They found that women who experienced high hurricane exposure were 3.3 times more likely to have a child born with low birth weight. However, there are a few limitations to this study. Most of the women were in the beginning stages of pregnancy at the time of Hurricane Katrina or were pregnant within 6 months of the hurricane, and these mothers may have different outcomes of women who game birth immediately following the storm. Also, this was a study with a small sample size, and relied on volunteers, so those who did not want to participate could not be included in the analysis. Callaghan (2007) finds higher percentage of children born with low birth weight in areas exposed to Katrina compared to those who were not. This study is simply a comparison, however, and does not include econometrics techniques and controls that would be necessary for analysis of a mechanism causing these results. Lastly, Simeonova (2011) estimates the impact of natural disasters in the United States on pregnancy outcomes. Although they are primarily interested in gestation periods, they do find a negative impact on birth weight that is statistically significant for any exposure during the 3-6 month period before delivery. They do caution that their study does have some limitations, such as estimates being skewed due to measurement error, and that since they do not know exactly who is impacted by the natural disasters, they are assign exposure to the hurricane to everyone, which makes it difficult to estimate the average treatment effect. Despite having many findings in the literature pointing to a negative impact of hurricanes on birth weight, there is one main study that finds no impact of hurricane exposure on birth weights. Currie and Rossin-Slater (2013) look at pregnancy outcomes of women exposed to hurricanes in Texas. In this study, they find no evidence of a relationship between hurricane exposure and birth weight (or gestational length). Although they find evidence of other negative health impacts of hurricanes at birth, low birth weight is not one of them.

There is also a vast literature of the impacts of other shocks or stressful situations on birth weight. Dancause (2011) studies the impact of a series of severe ice storms (causing power outages for long periods, up o 6 weeks long) on the birth outcomes of infants whose mother was affected by this while pregnant. Dancause determines higher prenatal maternal stress (PNMS) predict lower birth weights in general, especially if stressful exposure occurs midway through the pregnancy, although they do acknowledge that they do not have any information on women's general stress patterns, which makes it harder to interpret the stress levels measured as a result of the ice storms. Tan et al. (2009) investigate the birth outcomes of infants born to mothers who experienced a stressful earthquake during pregnancy. Using data from before and after the May 12, 2008 Wenchuan earthquake in southwestern China, they compare various pregnancy outcomes pre and post earthquake. The authors found statistical lower birth weight and a higher ratio of low birth weight in the post earthquake group compared to the pre earthquake group. This study is limited however, as the study only represents a small portion of the area impacted by the earthquake, and migration of people who moved out of the area after the earthquake posed a problem for gathering the proper information. In another study examining the impact of earthquakes on birth weights is Torche (2009), which examines the impact of an earthquake in Chile on birth weights. She finds an increase in cases of low birth weight as well as a decrease in the average birth weight for those exposed to a traumatic and high intensity earthquake in Chile. The author does acknowledge however, that the exclusion restriction (that stress is the only path of influence) does not necessarily hold, because there may be alternative paths of influence through which impacts occur.

Natural disasters can also be seen as a negative shock, rather than a stress, that may impact birth outcomes, but there are fewer studies examining this. The main study relating shocks to birth outcomes is a recent study by Rosales (2013) who estimates the impacts of the 1997-1998 El Niño flooding on birth outcomes of children in Ecuador. Here, the flood is a negative shock, impacting families in various ways. One way in which this shock impacts households directly is through the responses to these shocks, as households exposed to the adverse shock have lower total incomes than those not exposed. The findings on birth weight suggest that in utero exposure to the 1997-1998 El Niño increased the likelihood of low birth weight by 0.7 percentage points per months, not driven by preterm births. Morales calculates that being exposed to floods for three months while in utero, an infant is 2.2 percentage points more likely to be born with low birth weight. They measure the impact of El Niño on prenatal care and do not find a significant effect, suggesting their results are not driven by a lack of health care access, but rather due to stress or poor maternal nutrition. Morales notes that previous literature has found the impact of stress on birth weights most severe in the first trimester, and nutritional deficiencies have the largest impact on birth weights during the third trimester. When they look at the timing of in utero exposure, they estimate that exposure to this negative shock (a flood) during the third trimester increased the probability of being born with low birth weight by 2.3 percentage points.

Although all of these studies estimate the impacts of natural disasters (hurricanes and earthquakes) on birth outcomes, issues of sample size, migration, and lack of necessary econometric techniques (i.e. proper controls) amongst other problems limit their studies. We can clearly see that although there is at least one reputable study finding no impacts of hurricanes on birth weight, there is a general finding of negative impacts of natural disasters on birth weights.

3. Methodology

For this research, I use two main datasets to conduct the analysis. The data set documenting typhoon exposure comes from Hsiang (2010). This unique dataset constructed by Hsiang documents wind speed, temperature and precipitation exposure levels at the regional level for each of the 13 regions. The wind speed dataset is constructed using the LICRICE (Limited Information Cyclone Restoration and Integration for Climate Economics) model that constructs wind fields. Hsiang (2010) used this technique in creating a dataset on all the 2,246 storms that hit the Philippines in 1950-2008. (I only use the 1989-2008 wind field data). The dataset includes a single level of exposure for each region for each year, computed by taking the annual maximum wind speeds achieved for each storm in a region, then taking the average across the given region. I also have data on monthly typhoon exposure, which I am able to aggregate into a average regional typhoon exposure by quarter of the year, which is computed by taking the maximum wind speeds for storms in the given region for each quarter of each given year, and then taking the average of these storms across regions for each quarter of a given year. This data set fits the needs of this research as it allows the use of wind speed to determine storm intensity of the most severe storm, while controlling for variations in the area of a region. Wind speed is measured in meters per second (1 meter per second is roughly 2.24 miles per hour). As commonly utilized, I wind speed as the main measure of exposure, and the precipitation and temperature as climate controls.

I combine the data set of storm exposure with the DHS data to run the main analyses. The data on households comes from the Filipino Demographic and Health Survey, for the years 1993, 1998, 2003 and 2008. The dataset is administered to mothers of the household age 15-49.

This dataset has information on each child of the household (including birth statistics, where I get the birth weight data), as well as other important household information including but not limited to: assets, mother and father health and education statistics, and information on siblings. Each survey covers the year of the survey up until the survey is taken, as well as the previous 4 years (which would be the time since the last survey). The first dataset, the 1993 data, covers the information from the previous 4 years, which would mean the recall data goes back as far as 1989. The children's recode dataset is used for the analysis of birth weight. Since women are asked about children births in the recent past (more specifically, children born in the past 4 years plus the year up until the survey) I construct a panel dataset that has children born in each year of the span 1989-2008, all of whom are therefore under the age of 5.

This research is interested in the impact of typhoons on birth weight for everyone, but especially those who are at higher risk and may be impacted more adversely in several ways. Ideally, a measure of income, or a wealth index of some sort would be able to give this estimation of the impact of typhoons on birth weights for different economic subgroups of the population, however this dataset does not allow for a good estimation of wealth/socioeconomic status. Although the DHS dataset does include information on household assets, there are a few reasons why using this information to create an asset/wealth index does not fit the needs of this research. The first problem is that typhoon exposure may directly impact these assets that may be used potentially in a wealth index. For example, the material of the roof or the material of the dwelling may be impacted by typhoons—if a typhoon caused damage to a house, this may impact the asset factor, making these household characteristics not endogenous and not a good measure of socioeconomic status for the purposes of this study. Secondly, since the data set covers a total of 5 years and there is possible variation in the physical characteristics of the home, it is difficult to conclude with confidence that a family would have been in the exact same subgroup in the year of the survey that they were in the proceeding 4 years.

3.1 Identification Strategy

To empirically estimate the impact of tropical cyclones on birth outcomes, I exploit the variation in typhoon exposure for each region in the Philippines, and estimate the effect of the exposure to a tropical cyclone. It is important to address the idea that typhoons naturally transpire in different areas at varying intensities; some higher intensity and others lower intensity (Anttila-Hughes & Hsiang, 2013). With this natural variation however, it is possible that the cross sectional differences in average typhoon exposure may be correlated with the differences in unobservable characteristics of different regions. To minimize the impact of this possibility, I use region fixed effects in the analysis to control for these unobservable variables that may be any source of biased variation. This will absorb any potential regionally unique reasons why birth weights, measures in grams, may be lower in certain areas (i.e. do to differing practices amongst regions). Besides regional fixed effects, I also use year fixed effects and month fixed effects. Year fixed effects account for any characteristics and trends in behaviors that may vary from year to year. With these fixed effects, I account for common trend behavior as well as unobservable climate shocks, for example, El Niño (Greene, 2003). The month fixed effects control for any heterogeneity across months that may be present, or any monthly trends relating to changing and differing seasons.

The naturally occurring randomness of typhoon exposure originates from the idea that storm formation and trajectories are formed both naturally and randomly. However, since families can make location decisions based on seasonal typhoon predictions one source of discrepancy regarding the randomness of typhoons may be that annual variations may not be as random as anticipated. Although storm frequencies can be predicted fairly consistently, it is difficult to pinpoint exact locations that are at the highest risk during the storm season, especially since any of the regions or provinces in the Philippines are susceptible to typhoon exposure Typhoons can however be predicted with only a few days notice (Heming and Goerss, 2010), influencing people to take measures to protect themselves and/or their assets. The results are interpreted taking this into account, meaning the results we obtain are assumed to be the impacts of typhoons on birth weights after all of the potential adaptive behaviors have been undertaken. With such short notice however, it is unlikely to observe regional reorganization, which avoids a serious sorting affect driving these estimates.

The DHS data allows for a naturally sound empirical analysis, since any issues with sorting are naturally avoided and this data set that allows us to "follow" women over time. DHS data has information whether or not the family has ever lived somewhere besides their current location, as well as has information if they have lived there for the past 5 years (meaning since the last DHS survey was conducted in the area). Additionally, the data can "follow" a woman for the 5 years preceding the survey, since the survey covers the years leading up to the survey year. This gives information on the mother's history as well as the history of births, which allows for child to have their own identification code in the panel. The creation panel also allows for inferring siblings, as it is clear which children are born to which mother. As noted above, after creation of the child's panel I run regressions to determine the impact of typhoons on birth weights of these children.

4. Data Analysis

4.1 Sample Description

The typhoon dataset consisting of maximum wind speed, temperature and precipitation is gathered at the regional level (13 regions in total). Wind speed, our variable of interest, is measured by taking the LICRICE data on the maximum wind speed for each storm in a given region, and these maximum wind speeds across the given region. Wind speed is measured in meters per second (1 meter per second is roughly 2.24 miles per hour), which is what I use as a measure of storm intensity and temperature and precipitation are used as controls. The average maximum wind speed exposure in the Philippines over the years 1989-2008 is 16.9 m/s. The maximum wind speed exposure over these years is documented to be 43.53m/s and the minimum wind speed exposure is documented as 0 m/s. A full list of summary statistics for each region as well as the Philippines as a whole can be found in table 1 of the Appendix.

The Demographic and Health Survey is a household survey administered to the mothers in each household. The survey includes questions regarding: children's education, nutrition and health; maternal health, nutrition, behaviors and reproductive preferences; and husband and household characteristics. The survey is randomly administered to households every 5 years. The questions asked about children cover all children born to a mother over the last 5 years (i.e. if a woman had 3 children born in the last 5 years, she would answer the child portion of the survey 3 times, once for each child). After combining the DHS data from the years 1993, 1998, 2003, and 2008 with the wind speed data and taking only the non-migrants, there are 6,305 children in the dataset used for this analysis. In this dataset, the average of the outcome variable of interest, birth weight, is 3039.53 grams, with a standard deviation of 656.53, and 1,117 children out of the sample are classified as having low birth weight. (The threshold for being considered low birth weight is being born with a weight of 2500grams/5.5 pounds or less). Table 2 below provides a summary of various household characteristics as well as statistics on birth weight information.

TABLE 2
Demographic and Health Survey Summary Statistics

VARIABLE	Description	MEAN
Birth Weight	Weight at birth in grams	3039.53 (656.53)
VARIABLE	Description	TOTAL
Low Birth Weight	Children classified as being born with low birth weight (weighing less than 2500 grams at birth)	1,117
VARIABLE	DESCRIPTION	MEAN
Mother's Age	Age of mother in years	30.31 (6.54)
Mother's Education	Mother's highest grade completed	9.64 (3.91)
Father's Age	Age of Father in years	32.97 (7.34)
Father's Education	Father's highest grade completed	8.98 (3.72)
Household Size	Total number of household members	6.58 (2.68)
Total Children	Total number of children ever born to a given mother	3.44 (2.36)
VARIABLE	DESCRIPTION	TOTAL
Married	Number of married women	5,410
Unmarried	Number of unmarried women	895
Urban	Number women living in urban areas	3,015
Rural	Number of women living in rural areas	3,290
Total number of observations in the sample		6,305

4.2 Birth Weight Econometric Model (Yearly)

To empirically estimate the impacts of typhoons on birth weight, I run a simple ordinary least squares regression with a distributed lag model to predict the change in birth weight per 1 m/s increase in wind speed. The distributed lag model, allows for the examination of the impact of typhoon exposure on the birth weight of the child i for the year of birth as well 4 years leading up to the birth year. The regression therefore is

$$Y_{ijrt} = \sum_{L=0}^{4} \left[\alpha_L W_{r,t-L} + \beta_L T_{r,t-L} + \Upsilon_L R_{r,t-L} \right] \quad (1)$$

where *i* indicates a specific child, and *j* indicates a specific woman (the mother to child *i*), *r* indexes the region, *t* indexes the time in years. The outcome variable *Y* corresponds to the birth weight of child *i* measured in grams *W* is wind speed, *T* is temperature, and *R* is rainfall. This model however is very limited, as it does not control for household characteristics, time varying women specific characteristics, and unobservable region or year effects that may be driving the results. Therefore I expand the specification to measure the impact of typhoons on birth weight and the regression becomes:

$$Y_{ijrt} = \sum_{L=0}^{4} \left[\alpha_L W_{r,t-L} + \beta_L T_{r,t-L} + \Upsilon_L R_{r,t-L} \right] + \tau_t + \mu_r + \rho_r + \zeta H_{ij} + \delta X_{ij} + \varepsilon_{ijrt} \quad (2)$$

where τ is the year fixed effect, ρ is the month fixed effect, and, μ is the region fixed effect, *H* corresponds with household characteristics for child *i,* and corresponding mother *j* such as living in the rural or urban sector. *X* corresponds to the time varying traits of the mother, which includes age and age squared and observable traits such as highest level of education. The error term, ε, is the child specific error term, which encompasses any regional or household turbulences that may impact the birth weight of the child that are not explained here. Although I have information on household characteristics such as total children, household size, and birth order, which could be included in vector *H*, I leave these out of the specification because I am concerned that typhoon exposure may be endogenous to these variables, as previous typhoon exposure may be related to household characteristics, whereas typhoon exposure is not related to variables predetermined before a typhoon, such as the woman's characteristics of age, age squared and highest level of education. The temperature and precipitation measures are used as controls, as they may be impacting birth weights through another mechanism. Since the DHS data does not give the providence of residence, we the analysis is done at the regional level. I run the regressions with region, month and year fixed effects, and cluster the standard errors at the region-survey year level for the final model. I use clustered standard errors method since there is potentially some correlations of the standard errors within regions and within survey years, since the same people are not included in the surveys, and different people are administering the surveys each round. Again, the variable of interest is the coefficient on *W* (α_L), which estimates the impact of a 1 m/s increase in wind speed on birth weight in grams of a specific child, which we estimate with the distributed lag model.

Before arriving at the final specification, I run the model with simple OLS; OLS with woman's controls (age, age squared and education level); OLS with controls and year fixed effects; OLS with controls, year fixed effects and month fixed effects; and OLS with controls and year, month and region fixed effects. I arrive at the model of OLS with woman's controls and region, year and month fixed effects clustered at the region-survey year level which can be seen in table 3 of the, Appendix. All of these specifications were all run with and without the household controls I was concerned about being impacted by typhoons (total children and birth order) and there was a minimal difference in the coefficient and the significance was the remained for both, these household controls (birth order and total children) were omitted. In this model specification, we can see that OLS with region and year fixed effects is virtually the same as OLS with region and year fixed effects clustering at the region-survey year level. To see the complete progression of the model specification, refer to the Appendix, table 3.

4.3 Birth Weight Econometric Model (Quarterly)

The model for the impact of typhoons on birth weights refined to the quarterly level of exposure rather than yearly follows a similar specification to the year model:

$$Y_{ijrtq} = \sum_{L=0}^{8}\left[\alpha_L W_{r,t-L} + \beta_L T_{r,t-L} + \Upsilon_L R_{r,t-L}\right] + \tau_t + \mu_r + \rho_r + \zeta H_{ij} + \delta X_{ij} + \varepsilon_{ijrtq} \quad (3)$$

Where the only change is instead of lagging typhoon exposure each year, I lag typhoon exposure by quarter, which is represented by *q*. *q* for the year of birth would be 0, *q* for the quarter before birth would be the 1st lag, *q* for 2 quarters before birth would be the 2nd lag, and *q* for the 3 quarters before birth would be the 3rd lag, etc. The lags for maximum wind speed, temperature and precipitation go two years into the past, at the quarterly level, so there are 8 lags total. Again, The temperature and precipitation measures are used as controls, as they may be impacting birth weights through another mechanism. The coefficient of interest is α_L, which is the estimated impact of typhoon exposure per 1m/s for the child born in the given year, region and quarter. This model allows me to give a rough estimate of whether or not typhoon exposure in utero has different impacts on birth weight if exposure occurs in different trimesters. The quarter the child was born matches up with the climate data for that quarter of that year. Therefore by counting back, I can estimate the typhoon exposure for a given point in the pregnancy, give or take a few months, since the month of birth within a quarter may vary.

Once again, I run the model with simple OLS; OLS with woman's controls (age, age squared and education level); OLS with controls and year fixed effects; OLS with controls, year fixed effects and month fixed effects; and OLS with controls as well as region, year and month fixed effects. I arrive at the model of OLS with woman's and household controls and region fixed effects clustered at the region-survey year level. The progression of this model is shown in table 4 of the Appendix. All of these specifications were all run with and without the household controls I was concerned about being impacted by typhoons (total children and birth order) and there was a minimal difference in the coefficient (by tenths) and the significance remained, suggesting again that leaving out or keeping in total children and birth order is not resulting in any huge impacts. In this model specification, we can see that OLS with region, month and year fixed effects is virtually the same as OLS with region and year fixed effects clustering at the region-survey year level. Although insignificant, the coefficient is in the direction we would expect, as we expect increased wind speed to have a negative impact on birth weight, as seen in the main specification. To see the complete progression of the model specification, refer to the Appendix, table 4.

iv. Probability of Low Birth Weight Model (Yearly/Quarterly)

As a secondary way to estimate the impact of typhoons on birth weight, this research looks ay the potential change probability of low birth weight upon in utero exposure. For regressions estimating the impact of in utero typhoon exposure on increased probability of low birth weight, equations 2 and 3 are used with the same fixed effects, controls and clustering. The only difference is that the outcome variable in equation 2 is now Z_{ijrt}, which takes on a value between 0 and 1. Similarly, the outcome variable for equation 3 is now Z_{ijrtq}.

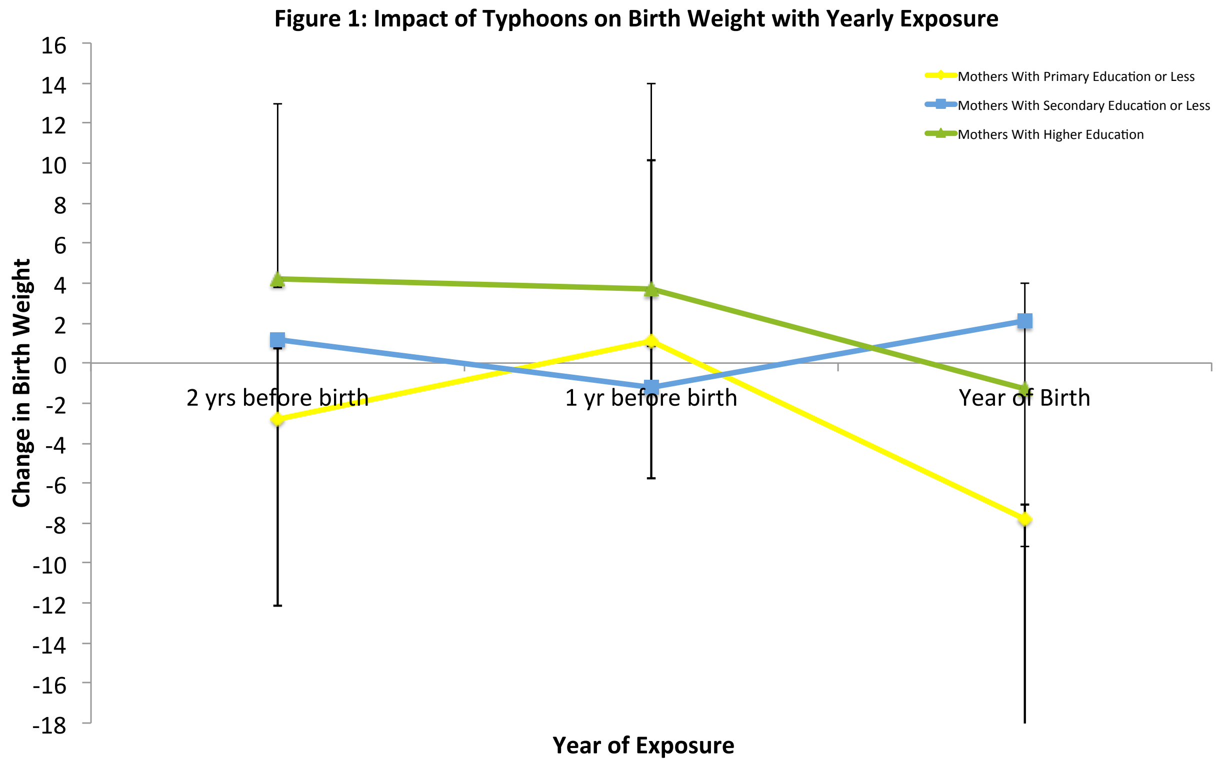
5. Results

5.1 Typhoons and Birth Weight: Exposure at the Yearly Level

All of the regressions I run are excluding twins and include only non-migrants children (the mothers have never moved from the current area). As seen when arriving at the main specification (column 5 of table 3 in the Appendix), there are no statistically significant impacts of typhoons on birth weights for those exposed to a typhoon in the year of birth, or for those whose household was exposed to a typhoon in the year prior to the year of birth for the child. However, the coefficient on for the year of birth (the maximum wind speed coefficient) is in the negative direction, which is what I would expect, however the same is not true for the 1-year lag coefficient (T-1). Since there seems to not be any relationship between birth weight and typhoon exposure in the previous year, which would have likely been an economic mechanism causing the results, my second null hypothesis can not be rejected. For the year of birth however, there seems to be a possible negative relationship between typhoons and birth weight. To see if there may indeed be a portion of the population that experiences a negative impact of typhoon exposure on birth weight, I stratify the sample into various subgroups of the population.

First, I run the main specification, diving the sample into male and female, and rural and urban and see no significant impacts of typhoons on birth weights for these subgroups. These results can be found in table 5 in the Appendix. The next stratification I am interested in analyzing is the impact of typhoons on birth weight for children born to households of differing socioeconomic status. As explained above, despite having information on certain household characteristics, which could be used as a means to determine approximate household wealth and socioeconomic status, there are two problems with this technique. The various variables available that would be used to create this wealth index may themselves be impacted by typhoons (i.e. variables related to housing structure). Because of this, it is hard to determine whether storms caused poverty and may result in lower birth weights, or if the families were already in poverty, and the typhoon therefore had even more detrimental impacts, which impacted birth weights. Additionally, the assets the women are asked about apply to the current state of the household—it does not necessarily apply to the past 5 years over which the survey covers. Therefore, it would be impossible to determine the measure of household wealth at the time of birth for children who were not born in the survey year.

Since education and socioeconomic status/wealth are likely to be correlated (despite the debate of which is driving which) I use woman's highest level of education as a proxy for socioeconomic status. I decided to divide the population into three groups. The three groups are: children exposed to a typhoon in utero born to mothers whose highest level of education is completion of primary school or lower; the second group is children born to mothers whose highest grade of school completed was somewhere in the secondary school range; and lastly children born to mothers whose highest level of education is higher than the last year of secondary. I find that children of households that experience a typhoon and have mothers of low education see a 7.830-gram per 1 m/s decrease in birth weight, which can be seen in Table 6 of the Appendix. Figure 1 below is a graphic representation of the impact of typhoon exposure measured at the yearly level for children born to mothers with differing levels of education. The solid line represents children born to mothers with primary education or less. As seen in the graph, if exposed in the year of birth, there is a much larger decrease in birth weight for this group of children born to mothers with the lowest levels of education. When I run this same regression but having probability of low birth weight as the outcome variable, I do not see any statistical significance in the same time periods, which can be seen in Table 7 of the Appendix.



5.2 Typhoons and Birth Weight: Exposure at the Quarterly Level

Since the impacts of typhoons on birth weight in the year of a typhoon for those born to mothers with primary education or less does not give a tight estimate of when exposure to a typhoon may impact birth weights, I run the regressions using exposure in the quarter of birth, and the preceding 3 quarters (which equals one year) to determine a tighter estimate of the exposure window that is driving the results. I use lags equal to two years, however these are not included in the regression tables below. As seen in column 6 of table 4 in the Appendix, the regression run with the full sample does not see any statistical significance in the impact of typhoons on birth weights in the quarter of birth or the preceding 3 quarters, however for typhoons during the quarter of exposure and the quarter before birth, there seems to be a negative relationship between typhoons and birth weight.

Next, I stratify the sample using the same subgroups as specified above (children born to women with primary education or less, children born to those with education up to some grade in the secondary range and lastly children born to those with mothers with higher education. Again, I restrict the sample to non-migrants and non-twins, and matched up the quarterly typhoon data with the child's quarter of birth, I am able to see when exposure while in utero seems to impact birth weights most. The variables new-maxs, new_maxsl1, new_maxsl2 and new_maxsl3 (shown in the regression table by Maximum Wind Speed, T-1, T-2, and T-3) each represent a 3 month period, so these four variables combined make up one year, which would cover all of the time the child was in utero. These are the wind speed variables climate variables that showed any sign of activity, so the lags 4 through 8 are left out of the regression tables.

Next, I stratify the data into children born to mothers of different levels of education, as done for the yearly typhoon exposure regressions in the previous section. In doing this, I can estimate for the given level of education for the mother, which quarter of exposure (in utero) to typhoons is driving the negative impact of typhoons on birth weight? I find that children born to mother's whose highest level of education is completion of primary or less see a 13.82-gram decrease in birth weight for each 1 m/s level increase in wind speed during the quarter of birth, which is significant at the 1% level. These regressions are shown below in table 8:

TABLE 8

Main Specification Stratified by Different Levels of Mother's Education (Quarterly)

	(1)	(2)	(3)
	Primary Completion or Less	Completion of grade somewhere in secondary range	Higher Education
VARIABLES	Birth Weight	Birth Weight	Birth Weight
Maximum Wind Speed	**-13.82*** **	1.985	4.369*
	(3.992)	(2.245)	(2.259)
T-1	0.871	-3.987	1.131
	(3.396)	(2.905)	(2.143)
T-2	-0.312	0.874	1.131
	(3.396)	(3.378)	(2.742)
T-3	3.182	-5.052	9.410**
	(5.606)	(3.157)	(4.131)
Observations	1,726	2,539	2,040
R-squared	0.083	0.042	0.063
Exposure	Region	Region	Region
Month FE:	X	X	X
Year FE:	X	X	X
Region FE:	X	X	X
Lagged Temp & Precip Controls	X	X	X
Household/Mother Controls	X	X	X
Standard Errors Clustered at the Region by Survey Year Level	X	X	X

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1, lags 4-8 left out of regression table

I also run this same specification, stratifying the sample by mother's highest level of education and estimate the increase in probability of low birth weight. I find that there is a 0.00568 increase in probability of a child being born low birth weight, per 1 m/s increase in typhoon intensity, for those children born to mothers with primary education, significant at the 1% level. This is also for the quarter of birth, meaning this coincides with the last trimester of gestation as well. These results are not surprising, as it coincides with the results of the birth weight regression above, and support the potential relationship between in utero typhoon exposure and low birth weight. These results can be seen below in table 9.

TABLE 9

Main Specification Stratified into Mother's Education Level (Quarterly)

	(1)	(2)	(3)
	Primary Completion or Less	Completion of grade somewhere in secondary range	Higher Education
VARIABLES	Probability of Low Birth Weight	Probability of Low Birth Weight	Probability of Low Birth Weight
Maximum Wind Speed	**0.00568*** **	-0.00154	-0.000890
	(0.00210)	(0.00120)	(0.00120)
T-1	0.000339	0.00146	-0.00304**
	(0.00188)	(0.00173)	(0.00126)
T-2	0.00155	-0.000609	0.00206
	(0.00226)	(0.00180)	(0.00144)
T-3	0.000504	0.00222	-0.00374**
	(0.00313)	(0.00211)	(0.00168)
Observations	1,726	2,539	2,040
R-squared	0.085	0.032	0.054
Exposure	Region	Region	Region
Month FE:	X	X	X
Year FE:	X	X	X
Region FE:	X	X	X
Lagged Temp & Precip Controls	X	X	X
Household/Mother Controls	X	X	X
Standard Errors Clustered at the Region by Survey Year Level	X	X	X

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1, lags 4-8 left out of regression table

Although there are indeed indications of negative impacts of typhoons on birth weights and the impacts seem small based on the coefficient alone, it is important to keep in mind that the coefficient is the result of a 1 m/s increase in wind speed. Since I calculate the average typhoon in the Philippines to be 16.9 m/s, each coefficient should be multiplied by 16.9 m/s to find out what the impact of average typhoon exposure on birth weight would be. For example, in the last result discussed, a 13.82 gram decrease in birth weights per 1 m/s increase in wind speed in the quarter of birth (to those born to mothers who had primary education or less) I would multiply 13.82 grams by 16.9 m/s (the average typhoon exposure). When I do this, I find that the average exposure would result in a child born that is 233.56 grams (about 8.23 ounces or 0.5 of a pound) less on average. Although this is not a huge number, keep in mind that for those who are close to the low birth weight threshold without typhoon exposure, this negative impact could push them into the low birth weight category. Also keep in mind that the maximum exposure was around 43.53 m/s, to in the case of a 13.82-gram decrease in birth weight for 1 m/s, this would result in on average a 629.22 gram (about 22.2 ounces or about 1.39 pounds) decrease in birth weight if maximum typhoon exposure as indicated by wind speed is reached. This potential decrease in birth weight due to typhoon exposure is just slightly smaller than the standard deviation of the average birth weight. A drop by this standard deviation is enough to reclassify a child from the normal birth weight category to the low birth weight category. This means that the worst typhoons may result in children being born with lower birth weights and maybe even being in the lower birth weight category if exposed while in utero, who also belong to mother's with the lowest levels of education. This is certainly a large impact, considering extremely devastating typhoons continue to impact the Philippines on almost a yearly basis.[1]

Also notable is a potential relationship between exposure and birth weight seen between males and females. For girls, if exposed earlier in the gestation period to a typhoon, it seems this may result in lower birth weights as seen in Table 10 of the Appendix. The same regression is run for probability of low birth weight, which is seen in Table 11, but there is no statistical significance. This gender difference is fairly surprising, since there is not a strong gender bias in the Philippines. Although this is the same DHS dataset as Anttila-Hughes & Hsiang (2013) and

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[1] At the yearly typhoon exposure level, children born to women with primary school or less see a 8.103 gram decrease in birth weight, which is a 136.94 gram decrease in birth weight for average exposure, and a 352.72 gram decrease in birth weight. For the quarterly estimates, average typhoon exposure would result in a lower birth weight for females by 103.41 grams and the highest level of storm exposure would result in lower birth weights of females by 266.36 grams.

they find evidence of a gender bias as well, with significantly higher infant mortality in females than males, the results are still intriguing. Therefore, this gender difference in birth weight for typhoon exposure is interesting and something that needs further research. The results again from the female/male and rural/urban stratification are shown are in Table 10 and Table 11 of the Appendix.

5.3 Nonlinear estimates of impacts of typhoons on birth weight

Since it is likely that the impacts of typhoons on birth weight may no be linear, I estimate the impact of typhoons on birth weight nonlinearly for the year and quarter of exposure, which can be seen in figures 1 and 2 at the end of the Appendix In both the yearly and quarterly estimates of the impact of typhoon on birth weight, there is some noise. However, we see an upward trend in the data, suggesting that lower levels of wind speeds not impact birth weights to the same degree as if the typhoon winds are more intense. This is fairly intuitive, wind speeds are more manageable at lower levels, but higher levels of wind speed are what cause extreme devastation and destruction. These storms are likely to be the ones that cause economic turmoil and/or stress, which I feel is driving the impact of typhoons on birth weights for certain groups. Overall however, the impact of typhoons on birth may not be truly captured since we do not have data on all of those children born during quarters or years of extreme storms. Adding observations to this analysis would help to determine if the impacts estimated in the quarterly estimate are truly plausible.

5.4 Robustness Checks

i. Expanding the sample

As a robustness check, instead of including only children born to mothers who have never moved, I expand the sample to include women who have lived in the current location for at least 5 years. This greatly increases my sample size, making it a little over twice the size of the original sample. When I add these children to the sample, the coefficients drop in magnitude, however there is still statistical significance on the same coefficients generated from the original regressions. The coefficient for the regression of children born to women with primary education or less (column 1 of table 9) now has a coefficient of -6.364, but it is still significant (at the 5% level however instead of the 1% level). This can be found in table 12 of the Appendix. Similarly, table 13 of the Appendix shows the expanded sample regression of the impact of typhoon exposure on probability of low birth weight, for the three different levels of mother's education. In this case also, there is no longer statistical significance with this sample in estimating the impact of typhoon exposure on probability of low birth weight. The results are also shown below in tables 12 and 13 below.

TABLE 12

Robustness Check (mother years resident >5): for the Main Specification by different levels of mother's education (Quarterly)

	(1)	(2)	(3)
	Primary Completion or Less	Completion of grade somewhere in secondary range	Higher Education
VARIABLES	Birth Weight	Birth Weight	Birth Weight
Maximum Wind Speed	**-6.364****	-0.219	2.107
	(2.614)	(1.744)	(1.745)
T-1	2.833	-2.172	0.926
	(2.940)	(1.741)	(1.684)
T-2	-1.867	0.0368	-1.459
	(2.537)	(1.800)	(1.879)
T-3	1.732	-2.630	6.155*
	(2.433)	(2.177)	(3.084)
Observations	3,562	5,602	4,015
R-squared	0.056	0.026	0.032
Exposure	Region	Region	Region
Month FE	X	X	X
Year FE:	X	X	X
Region FE:	X	X	X
Lagged Temp & Precip Controls	X	X	X
Household/Mother Controls	X	X	X
Standard Errors Clustered at the Region by Survey Year Level	X	X	X

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1, lags 4-8 left out of regression table

TABLE 13

Robustness Check (mother's years resident >5): Main Specification by different levels of mother's education (quarterly)

	(1)	(2)	(3)
	Primary Completion or Less	Completion of grade somewhere in secondary range	Higher Education
VARIABLES	Probability of Low Birth Weight	Probability of Low Birth Weight	Probability of Low Birth Weight
Maximum Wind Speed	0.00183	2.17e-05	0.000132
	(0.00137)	(0.000963)	(0.000910)
T-1	-0.000648	0.000401	-0.00206*
	(0.00110)	(0.00106)	(0.00109)
T-2	0.00109	-4.51e-05	0.00158
	(0.00167)	(0.00109)	(0.00100)
T-3	0.00110	0.00124	-0.00116
	(0.00146)	(0.00147)	(0.00134)
Observations	3,562	5,602	4,015
R-squared	0.055	0.019	0.026
Exposure	Region	Region	Region
Year FE:	X	X	X
Region FE:	X	X	X
Lagged Temp & Precip Controls	X	X	X
Household/Mother Controls	X	X	X
Standard Errors Clustered at the Region by Survey Year Level	X	X	X

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1, lags 4-8 left out of regression table

ii. Interaction Term

As a second kind of robustness check, I interact children born to mothers with primary education or less and the maximum wind speed for the quarter or birth. This provides a solid robustness check as it allows for analysis of the full sample, instead of stratification of the sample into different levels of mother's education. With this interaction term, I find a coefficient of -11.14, significant at the 1% level. This suggests that per 1 m/s increase in typhoon exposure there will be a decrease in birth weight by 11.14-grams, for those who are born to mothers with primary school or less and exposed in the quarter of birth. This conclusion coincides with the regressions in the results section above, suggesting that again there is likely to be a relationship between typhoon exposure and birth weights for children born to mothers who have primary education or less. With this sample, there is much more power, since the full sample is used, which gives more evidence to support this possible relationship between in utero typhoon exposure and birth weights. The full results of these regressions can be seen in table 14 of the Appendix. When I run this same regression using probability of low birth weight, as the outcome variable instead, the interaction term is once again still significant. These regression results can be seen in table 15 of the Appendix. The coefficient on the interaction term is 0.00595, significant at the 1% level. This once again suggests with more power, that I utero typhoon exposure may indeed increase the probability of low birth weights. Tables 14 and 15 are shown below to illustrate the full results.

TABLE 14

Robustness check: Full sample with Education*New_Maxs interaction term

	(1)	(2)	(3)
VARIABLES	Birth Weight	Birth Weight	Birth Weight
Maximum Wind Speed	1.743	-2.704*	-2.560
	(1.742)	(1.556)	(2.007)
T-1	-0.717	-0.450	-0.646
	(1.516)	(1.525)	(1.509)
T-2	-0.111	-0.174	-0.0158
	(1.851)	(1.869)	(1.846)
T-3	2.478	2.541	2.464
	(1.833)	(1.853)	(1.812)
Mother's Education Primary or Lower	-6.670		
	(27.88)		
Primary*New_Maxs	**-11.14*** **		
	(3.242)		
Mother's Education in Secondary Range		-2.399	
		(23.21)	
Secondary*New_maxs		4.055*	
		(2.189)	
Mother's Education Greater than Secondary			8.375
			(26.20)
Higher*New_maxs			4.900*
			(2.710)
Observations	6,305	6,305	6,305
R-squared	0.034	0.031	0.031
Exposure	Region	Region	Region
Month FE:	X	X	X
Year FE:	X	X	X
Region FE:	X	X	X
Lagged Temp & Precip Controls	X	X	X
Household/Mother Controls	X	X	X
Standard Errors Clustered at the Region by Survey Year Level	X	X	X

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1, lags 4-8 left out of regression table

TABLE 15

Main Specification by different levels of mother's education with interaction (quarterly)

	(1)	(2)	(3)
VARIABLES	Child Low Birth Weight	Child Low Birth Weight	Child Low Birth Weight
Maximum Wind Speed	-0.000956	0.00202**	0.000812
	(0.000707)	(0.000838)	(0.000988)
T-1	-0.000510	-0.000675	-0.000599
	(0.000872)	(0.000870)	(0.000895)
T-2	0.000759	0.000780	0.000707
	(0.00107)	(0.00108)	(0.00106)
T-3	-0.000208	-0.000251	-0.000239
	(0.00104)	(0.00106)	(0.00105)
Primary Education	0.0262		
	(0.0158)		
Primary* New_maxs	**0.00595*** **		
	(0.00190)		
Mother's Education in Secondary Range		0.00369	
		(0.0131)	
Secondary*New_maxs		-0.00354***	
		(0.00123)	
Mother's Education Higher than Secondary			-0.0272*
			(0.0142)
Higher*New_maxs			-0.00104
			(0.00130)
Constant	0.432	0.498	0.445
	(0.957)	(0.960)	(0.960)
Observations	6,305	6,305	6,305
R-squared	0.030	0.027	0.027
Exposure	Region	Region	Region
Month FE	X	X	X
Year FE:	X	X	X
Region FE:	X	X	X
Lagged Temp & Precip Controls	X	X	X
Household/Mother Controls	X	X	X
Standard Errors Clustered at the Region by Survey Year Level	X	X	X

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1, lags 4-8 left out of regression table

iii. Mother's Fixed Effects & Clustered FE

Lastly, as a robustness check, I run the quarterly specification stratified by mother's level of education, but with woman's/mother's fixed effects instead of region fixed effects, which can be found in table 16 of the Appendix. Also, I run the main specification stratified by mother's level of education and use cluster fixed effects instead of region fixed effects, which can be found in table 17 of the Appendix. When I run the mother's fixed effects, for the children born to mothers with primary education or less, the statistical significance of exposure in the quarter of birth does not remain, however the coefficient is still in the negative direction (although smaller), which is consistent with the results of the regressions with the region fixed effects instead of mother's fixed effects. When I use cluster fixed effects however, there is a decrease in birth weight of 9.598 grams per 1 m/s increase in wind speed, statistically significant at the 5% level for children born to mother's who have primary education or less and exposed in the quarter of birth (coinciding with the last trimester of gestation). The magnitude is slightly smaller than the results in the main regressions of the paper, however the results are for the most part consistent. This suggests that clustering at the region level or the cluster level is an acceptable technique. Some clusters in this sample end up being small after I take into account only the non-twins and non-migrants, however the statistical significant holds with both the region fixed effects and the clustered fixed effects, suggesting that there indeed seems to be a relationship between typhoon exposure in utero and birth weights

6. Discussion

Since birth weight is an important indicator for overall infant health as well as an indicator for future economic and schooling outcomes, this research sought to see whether or not typhoons impact birth weights. The decisions made during pregnancy that impact the mother's health directly and therefore the fetus' health can be looked at as human capital investments. Therefore, the goal of this research was to see whether or not these types of human capital investments change in the wake of typhoon exposure, which may manifest itself in the potential changes in birth weight of children exposed in utero.

The results found in this research are more or less what would be expected based on theory and other empirical work. In the regression with yearly lags, there are no rural or urban or gender differences that can be seen in the analysis, nor are there any gender differences apparent.

The result that I do find however is a 7.830 gram decrease in birth weight per 1 m/s increased typhoon exposure in the year of a storm for children born to women with the lowest levels of education, suggests that those whose mothers have only completed primary school or less may have difficulty coping with typhoon exposure. It is possible that at lower levels of education, women are unaware of how health and nutrition changes may impact their fetus. This may suggest that lower birth weights in the wake of a typhoon may be a result of mothers not having the education/knowledge regarding the impacts of mother's decisions on the fetus while in utero. Another possible explanation for these results based on education levels may be that the year of a typhoon causes a stress on the mother, which can cause infants to be born prematurely and/or with lower birth weights. This stress could be the stress of the traumatic event itself, or it could be that a storm brings different stresses, including economic stress to a household, which can impact the pregnancy.

Although yearly typhoon exposure is important to analyze, it is not as concise as the same analysis on quarterly typhoon exposure, which gives more insight into the timing of exposure. When the same regression was run with the total population analysis but looking at exposure by quarter of the year, the results show no significant impact of typhoons on birth weight, although the regression certainly suggests negative impacts.

When I stratify the sample by mother's highest level of education, the results of the impact of typhoons on birth weight as the quarterly level of exposure suggest there is indeed an impact of typhoons on birth weights, but now I can narrow it analysis down to the trimester level and obtain a better estimate of the exposure window that is most detrimental. According to a previous literature (Rosales 2013) poor nutrition inputs during the third trimester are more likely to impact birth weights, whereas stress is the main driver of lower birth weights if it occurs in the first trimester. For this research, the quarter of birth would coincide with the 3rd trimester of pregnancy, depending on when in the quarter the child was born. For children born in the beginning of the quarter of birth, their third trimester may include months from the quarter of birth as well as the 1st lag, but for those born later in the quarter, the third trimester probably includes most of the quarter of birth only[2]. In the regressions with quarterly climate data, typhoon exposure in the quarter of birth suggests lower birth weights by 13.82 per 1m/s of typhoon exposure for children born to women with primary education or less, but not in any of the quarters proceeding the birth quarter. The birth quarter results suggest that typhoon

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[2] Using this logic, we can see how the first trimester can be anywhere between the second lag to the third lag, and the second trimester may be anywhere from the first to the second lag. Although I do not look at typhoon exposure for month of birth, this strategy still gives a decent estimate if exposure while in utero may impact birth weights, and through which possible mechanism this is happening according to medical literature.

exposure in the third trimester for those children whose mother had primary education or less, impacts birth weights negatively and significantly. A possible explanation for this could once again be stress, economic or physical. Another possible explanation however could be that typhoon exposure in the trimester of birth (the trimester where nutrition has the most impact on birth weights and where weight gain occurs most rapidly), may be impacting children born to women with the lowest levels of education due to the lack of information regarding the importance of nutrition during the third trimester. If a household where the mother has primary school education or less is impacted negatively by a typhoon (i.e. negative economic impact on the household), it is possible that the mother may not be aware that changing nutrition and health inputs during these last months of pregnancy may impact the fetus negatively. Also this is evidence that people with higher levels of education have undertaken adaptive behaviors to cushion themselves from these types of impacts of the shocks. Knowledge of coping strategies may increase with education level, suggesting that education levels are very important.

The main result from analyzing the data by gender and rural households versus urban households is that rural and urban households seem to have no difference in the impact of typhoons on birth weight. This is consistent with Anttila-Hughes and Hsiang (2013) who do not find any rural or urban difference in disinvestment in infants and infant mortality in the wake of typhoons in the Philippines. Interestingly, when the sample is stratified by gender, there I see a significant impact of typhoons on birth weight for females in the second lag, which corresponds to two quarters before the birth quarter. Though this warrants more research, these results are interesting and may suggest that typhoon exposure anywhere from the first trimester or second trimester depending on the birth month of the child coincides with lower birth weights for females, 5.545 per 1m/s increase in wind speed. This is interesting because there is not a strong gender bias in the Philippines. This result could simply be a coincidence, however there are other potential explanations. Since abortion is illegal in the Philippines, it is possible that sex selective abortion may be present in some households. Sex selective abortion would require that a household knows the gender of the baby, and then based on this information may make different health and nutrition decisions (Arnold et al, 2002). This is a possibility in this research, since the exposure during this specific quarter may coincide with the second trimester, where the gender of the fetus may be revealed. Since ultrasounds are a common practice today, it seems possible that upon finding out the gender, women make different decisions regarding inputs that may impact human capital outputs. If a family does not want a girl, they may choose to not invest as much in the health and nutrition of the baby. Again, there is not a strong gender bias in the Philippines, but this finding as well as Anttila-Hughes & Hsiang (2013)'s finding on increased infant mortality for females only the year after a storm, suggest that families may indeed be investing differently in their children and that gender may be important. However, this possible gender bias and difference in birth weights may not be explained by sex selective abortion or coincidence, and needs to be further investigated to find possible reasons, mechanisms and explanations to determine if this result is robust and may actually occur in the Filipino culture.

7. Conclusion

The main objective of this study was to determine if in utero typhoon exposure, or household exposure in the year prior to birth, have a negative impact on birth weights of children. Birth weights are important health indicators for newborns, as well as indicators of later life outcomes such as health, education and earnings. Previous literature has found an overall negative impact of an external shock such as a natural disaster on birth weights. Some of these impacts may be attributed to stress (Dancause 2011, Tan et al 2009, Xiong et al. 2008, Simeonova 2011, Torche 2009, Callaghan 2007), or they could also be a result of be the result of economic impacts that change household behaviors (Rosales 2013) Other literature such as Currie and Rossin-Slater (2013) has found that there is no impact of typhoons on birth weight. Currie and Rossin-Slater (2013) also used their data but estimated with the same techniques that resulted in negative impacts of natural disasters and typhoon on birth weight, and had they used that estimation they would have also found this negative impact. (They stick by their finding however, of no impact of storms on birth weight.)

This research contributes to the literature as it adds to the growing literature of the longer-term potential impacts of natural disasters. Besides the physical damages, this study finds negative impacts on birth weights with yearly and quarterly storm exposure for certain subgroups of the population. These low birth weights may impact later life outcomes through lower education level, lower earnings or possibly adverse health outcomes. This study brings attention to the fact that the birth weight of children born to mothers with lower levels of education are impacted by typhoon exposure significantly, which is seen in the analysis of birth year typhoon exposure as well as the analysis of birth quarter typhoon exposure. Additionally, through the birth quarter analysis of the impact of typhoons on birth weight shows a gender differential, with females seeing statistically significant lower birth weights as a result of typhoon exposure in the birth quarter, but not for males. This is interesting again because the Philippines is not a country known for gender inequality. These findings contribute not only to the growing literature on natural disasters and birth weights, but also literature on the education, health and development, and possibly the gender literature, but also need to be further investigated.

Based on the results, policy recommendations could include campaigns to stress the importance of nutrition and health for pregnant women. In the wake of a typhoon, it may be difficult for families to make ends meet, however it should be stressed that it is important that pregnant women ensure that the proper health and nutrition measures are taken. If the problem is more that the health and nutrition essentials simply are not available, then policy should focus on ensuring that relief procedures include resources to ensure pregnant women are able to receive the proper aid. Policy recommendations regarding the gender difference in birth weights is harder to address, and most likely further research in this area is needed to address the issue. Further research is also needed understand the exact mechanism in which typhoons are impacting birth weights of children born to mothers with lower levels of education. Part of this may include expanding the sample size and being able to see if this result holds over a larger sample within the Philippines. Additionally, since the impacts of typhoons on birth weight for children born to mothers with lower levels of education are only seen in the quarter of exposure, further research is needed to rule out the possibility that typhoons may also be impacting the fetus in other ways that simply do not manifest themselves in the form of low birth weights. There could be other fetal health or cognitive indicators that this research does not have, but that could be impacted by typhoons if exposed in earlier trimesters. Lastly, for future research, it would also be helpful to run the same analysis on other countries with similar climate patterns to determine if this impact is seen in other countries. If these results are widespread, the policy recommendations stemming from these studies may lead to improved relief and response to natural disaster, as well as better preparations to help households cope with large storms.

Despite the interesting results, there are certainly limitations of this study. Although the Demographic and Health Data is large, our sample is restricted to only non-migrants, so the sample becomes smaller. Adding more data would greatly improve the analysis of the impact of typhoons on birth weight. Additionally although education and socioeconomic status are indeed highly correlated, having a more precise measure of socioeconomic status would help this research, as it would ensure that the children are indeed in the correct socioeconomic status category. Lastly, this study is not able to untangle whether these impacts on birth weight are economic or stress driven, and it would require many more observations to examine this impact at the monthly level. Despite not being able to determine this, birth weights are indeed an important area to explore and determine if indeed natural disasters are having a negative impact on birth weight as other studies have found.

References

Almond, D., & Currie, J. (2011). Killing me softly: The fetal origins hypothesis. *The Journal of Economic Perspectives*, *25*(3), 153-172.

Anttila-Hughes, J. K., & Hsiang, S. M. (2013). *Destruction, disinvestment, and death: Economic and human losses following environmental disaster*. Working paper. Columbia University.

Arnold, F., Kishor, S., & Roy, T. K. (2002). Sex-Selective Abortions in India. *Population and development review*, *28*(4), 759-785.

Barker, D. J. (1995). Fetal origins of coronary heart disease. *BMJ: British Medical Journal*, *311*(6998), 171.

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

Black, S. E., Devereux, P. J., & Salvanes, K. G. (2007). From the cradle to the labor market? The effect of birth weight on adult outcomes. *The Quarterly Journal of Economics*, *122*(1), 409-439.

Callaghan, W. M., Rasmussen, S. A., Jamieson, D. J., Ventura, S. J., Farr, S. L., Sutton, P. D., ... & Posner, S. F. (2007). Health concerns of women and infants in times of natural disasters: lessons learned from Hurricane Katrina. *Maternal and Child Health Journal*, *11*(4), 307-311.

Currie, J., & Rossin-Slater, M. (2013). Weathering the storm: Hurricanes and birth outcomes. *Journal of health economics*.

Currie, Janet, and Rosemary Hyson. 1999. "Is the Impact of Health Shocks Cushioned by Socioeconomic Status? The Case of Low Birthweight." *American Economic Review*, 89(2): 245–50.

Dancause, K. N., Laplante, D. P., Oremus, C., Fraser, S., Brunet, A., & King, S. (2011). Disaster-related prenatal maternal stress influences birth outcomes: Project Ice Storm. *Early human development*, *87*(12), 813-820.

del Ninno, C., & Dorosh, P. A. (2002). Maintaining food security in the wake of a natural disaster: policy and household response to the 1998 floods in Bangladesh. *Journal of Bangladesh Studies*, *4*(1), 12-24.

Grossman, M. (2000). The human capital model. *Handbook of health economics*, *1*, 347-408.

Greene, William H., Econometric Analysis, Fifth Edition (Prentice Hall, 2003)

Heming, Julian and Jim Goerss, Track and Structure Forecasts of Tropical Cyclones" (2010)."

Hsiang, S. M. (2010). Temperatures and cyclones strongly associated with economic production in the Caribbean and Central America. *Proceedings of the National Academy of Sciences*, *107*(35), 15367-15372.

IPCC, Climate Change 2007 - The Physical Science Basis (Cambridge University Press, 2007).

Paul, S. K., Paul, B. K., & Routray, J. K. (2012). Post-Cyclone Sidr nutritional status of women and children in coastal Bangladesh: an empirical study. *Natural hazards*, *64*(1), 19-36.

Rosales, M., (2013), Impact of Early-Life Shocks on Human Capital Formation: Evidence from El Niño Floods in Ecuador. Job market paper. University of Chicago

Simeonova, E. (2011). Out of Sight, Out of Mind? Natural Disasters and Pregnancy Outcomes in the USA. *CESifo Economic Studies*, *57*(3), 403-431.

Tan, C. E., Li, H. J., Zhang, X. G., Zhang, H., Han, P. Y., An, Q., ... & Wang, M. Q. (2009). The impact of the Wenchuan earthquake on birth outcomes. *PLoS One*, *4*(12), e8200.

Torche, F. (2011). The effect of maternal stress on birth outcomes: exploiting a natural experiment. *Demography*, *48*(4), 1473-1491.

Xiong, X. U., Harville, E. W., Mattison, D. R., Elkind-Hirsch, K., Pridjian, G., & Buekens, P. (2008). Exposure to Hurricane Katrina, post-traumatic stress disorder and birth outcomes. *The American journal of the medical sciences*, *336*(2), 111.

APPENDIX

TABLE 1

Average max wind speed, temperature and precipitation over the years 1989-2008

REGION	Mean	Std. Dev	Min	Max
Bicol				
Max Wind speed	21.65643	8.85756	9.400024	39.11769
Temp	28.2564	0.2976643	27.60051	28.82343
Precip	79.29012	15.07657	52.7784	105.3315
Cagayan Valley				
Max Wind speed	27.78602	8.286306	11.94944	43.53289
Temp	27.27993	0.3070365	26.87383	27.98582
Precip	70.34612	10.83193	49.08081	95.01741
Central Luzon				
Max Wind speed	21.14388	7.897484	9.19107	34.67519
Temp	27.52551	0.2558648	27.19348	28.17496
Precip	82.77231	10.50188	56.68043	101.9976
Central Visayas				
Max Wind speed	13.15765	5.835042	5.685969	28.22167
Temp	27.5067	0.2577902	26.84143	27.95408
Precip	63.66002	13.20404	42.37687	89.32388
Corillera Admin Region				
Max Wind speed	26.64238	8.014589	11.67923	40.11093
Temp	27.11911	0.2996651	26.73405	27.83888
Precip	73.87411	10.2437	52.43696	96.92813
Eastern Visayas				
Max Wind speed	17.66716	7.003622	6.860119	32.09995
Temp	28.04692	0.2571317	27.4204	28.51364
Precip	70.84786	14.25773	48.18497	99.30719
Ilocos				
Max Wind speed	23.90981	6.665393	11.97138	36.65676
Temp	27.15404	0.3121161	26.74536	27.95863
Precip	74.50829	8.762462	54.05886	93.06374
National Capital Region				
Max Wind speed	20.95349	9.324961	7.709559	39.94063
Temp	27.4515	0.2617152	27.06667	28.03083
Precip	79.9175	12.52987	52.69	102.46
Northern Mindanao				
Max Wind speed	9.116235	3.944469	2.364804	18.26682
Temp	25.61994	0.252349	25.22895	26.36787
Precip				
Sounthern Minadao				
Max Wind speed	3.144335	2.748184	0	8.645976
Temp	26.57259	0.1761384	26.32481	27.05191
Precip	65.41338	13.21199	42.52421	91.83178
Southern Tagalog				
Max Wind speed	16.57516	5.324459	7.660014	26.6951
Temp	28.06755	0.2474721	27.6371	28.64664
Precip	79.44912	11.83887	54.73298	102.2748
Western Visayas				
Max Wind speed	15.79219	6.663646	6.836553	31.69591
Temp	27.82676	0.2849918	27.1138	28.33411
Precip	71.24404	12.86332	49.93126	94.91261
Zamboanga Penninsula				
Max Wind speed	3.402156	3.324656	0	9.771995
Temp	28.02502	0.1891496	27.68369	28.40696
Precip	68.41593	13.6484	45.35675	95.88821
Philippines Overall				
Max Wind speed	16.99592	10.14487	0	43.53289
Temp	27.41938	0.7386906	25.22895	28.82343
Precip	73.05578	13.50934	42.37687	105.3315

NOTE: Wind speed measured in m/s, temperature measured in degrees Celsius, and precipitation measured in millimeters per 24 hour period

TABLE 2
Demographic and Health Survey Summary Statistics

VARIABLE	Description	MEAN
Birth Weight	Weight at birth in grams	3039.53 (656.53)
VARIABLE	Description	TOTAL
Low Birth Weight	Children classified as being born with low birth weight (weighing less than 2500 grams at birth)	1,117
VARIABLE	DESCRIPTION	MEAN
Mother's Age	Age of mother in years	30.31 (6.54)
Mother's Education	Mother's highest grade completed	9.64 (3.91)
Father's Age	Age of Father in years	32.97 (7.34)
Father's Education	Father's highest grade completed	8.98 (3.72)
Household Size	Total number of household members	6.58 (2.68)
Total Children	Total number of children ever born to a given mother	3.44 (2.36)
VARIABLE	DESCRIPTION	TOTAL
Married	Number of married women	5,410
Unmarried	Number of unmarried women	895
Urban	Number women living in urban areas	3,015
Rural	Number of women living in rural areas	3,290
Total number of observations in the sample		6,305

TABLE 3

Progression of the Econometric Model (Yearly)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Birth Weight	Birth Weight	Birth Weight	Birth Weight	Birth Weight	Birth Weight
Maximum Wind Speed	0.455	0.291	-2.193	-2.193	-1.217	-1.217
	(1.254)	(1.254)	(1.651)	(1.652)	(1.988)	(1.715)
T-1	-0.436	-0.529	-0.852	-0.810	0.164	0.164
	(1.206)	(1.206)	(1.535)	(1.536)	(1.927)	(1.892)
T-2	1.190	1.183	0.652	0.674	1.282	1.282
	(1.184)	(1.183)	(1.419)	(1.421)	(1.662)	(1.255)
T-3	-0.117	-0.0188	0.00774	-0.0527	-0.256	-0.256
	(1.207)	(1.207)	(1.395)	(1.399)	(1.778)	(1.664)
T-4	0.673	0.610	1.569	1.533	1.664	1.664
Observations	6,305	6,296	6,296	6,296	6,296	6,296
R-squared	0.004	0.007	0.014	0.015	0.030	0.030
Exposure	Region	Region	Region	Region	Region	Region
Month FE:				X	X	X
Year FE:			X	X	X	X
Region FE:					X	X
Lagged Temp & Precip Controls	X	X	X	X	X	X
Household/Mother Controls		X	X	X	X	X
Standard Errors Clustered at the Region by Survey Year Level						X

Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1

TABLE 4

Progression of the Econometric Model (Quarter Lags)

	(1)	(2)	(3)	(4)	(5)	(6)
Maximum Wind Speed	-0.00173	0.0730	-0.625	-0.248	-0.962	-0.962
	(1.491)	(1.490)	(1.524)	(1.571)	(1.604)	(1.555)
T-1	0.497	0.450	-0.0569	0.173	-0.494	-0.494
	(1.581)	(1.581)	(1.602)	(1.654)	(1.671)	(1.525)
T-2	1.217	1.270	0.600	0.500	-0.104	-0.104
	(1.708)	(1.707)	(1.732)	(1.771)	(1.791)	(1.856)
T-3	4.614**	4.414**	3.979**	3.724*	2.507	2.507
	(1.856)	(1.856)	(1.882)	(1.921)	(1.942)	(1.828)
T-4	-0.115	-0.231	-0.434	-0.694	-0.283	-0.283
	(1.891)	(1.893)	(1.906)	(1.940)	(1.948)	(1.985)
T-5	-2.757	-2.810	-3.339*	-4.091**	-3.724*	-3.724**
	(1.827)	(1.826)	(1.851)	(1.919)	(1.922)	(1.744)
T-6	1.114	1.052	0.0328	-0.596	-0.237	-0.237
	(1.792)	(1.792)	(1.809)	(1.856)	(1.850)	(1.945)
T-7	0.356	0.253	0.317	0.502	0.452	0.452
	(1.784)	(1.784)	(1.806)	(1.833)	(1.825)	(1.298)
T-8	1.432	1.327	0.789	1.072	-0.180	-0.180
	(1.727)	(1.726)	(1.738)	(1.783)	(1.802)	(1.846)
Observations	6,305	6,305	6,305	6,305	6,305	6,305
R-squared	0.006	0.008	0.014	0.015	0.031	0.031
Exposure	Region	Region	Region	Region	Region	Region
Month FE:				X	X	X
Year FE:			X	X	X	X
Region FE:					X	X
Lagged Temp & Precip Controls	X	X	X	X	X	X
Household/Mother Controls		X	X	X	X	X
Standard Errors Clustered at the Region by Survey Year Level						X

Standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1

TABLE 5

Main Specification Broken into Female/Male and Rural/Urban (Yearly)

	(1)	(2)	(3)	(4)
	Female	Male	Rural	Urban
	Birth Weight	Birth Weight	Birth Weight	Birth Weight
Maximum Wind Speed	-1.807	-0.895	-1.198	-1.642
	(2.753)	(2.717)	(2.472)	(2.182)
T-1	-2.506	1.962	0.891	-0.733
	(2.601)	(2.584)	(3.019)	(2.254)
T-2	1.241	0.953	1.787	0.873
	(2.240)	(1.889)	(1.941)	(1.921)
T-3	-2.907	1.581	-0.763	0.278
	(2.348)	(1.963)	(2.739)	(1.873)
T-4	1.542	1.966	-1.462	5.034**
	(2.491)	(2.214)	(2.465)	(2.118)
Observations	2,961	3,344	3,290	3,015
R-squared	0.036	0.041	0.038	0.042
Exposure	Region	Region	Region	Region
Month FE:	X	X	X	X
Year FE:	X	X	X	X
Region FE:	X	X	X	X
Lagged Temp & Precip Controls	X	X	X	X
Household/Mother Controls	X	X	X	X
Standard Errors Clustered at the Region by Survey Year Level	X	X	X	X

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1, lags 4-8 left out of regression table

TABLE 6

Main Specification by different levels of mother's education (yearly)

	(1)	(2)	(3)
	Primary Completion or Less	Completion of grade somewhere in secondary range	Higher Education
	Birth Weight	Birth Weight	Birth Weight
Maximum Wind Speed	-7.830**	2.096	-1.29
	-3.515	-4.034	-3.279
T-1	1.1	-1.233	3.698
	-3.963	-3.102	-3.265
T-2	-2.834	1.205	4.184*
	-3.171	-2.452	-2.278
T-3	-7.933**	1.591	1.7
	-3.763	-2.662	-2.408
T-4	0.354	0.54	3.536
	-3.584	-2.433	-2.441
Observations	1,726	2,539	2,040
R-squared	0.068	0.037	0.055
Month FE:	X	X	X
Year FE:	X	X	X
Region FE:	X	X	X
Lagged Temp & Precip Controls	X	X	X
Household/Mother Controls	X	X	X
Standard Errors Clustered at the Region by Survey Year Level	X	X	X

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1, lags 4-8 left out of regression table

TABLE 7

Main Specification estimating probability of low birth weight by different levels of mother's education (Yearly)

	(1)	(2)	(3)
	Primary Completion or Less	Completion of grade somewhere in secondary range	Higher Education
VARIABLES	Probability of Low Birth Weight	Probability of Low Birth Weight	Probability of Low Birth Weight
Maximum Wind Speed	0.00211	-0.000548	0.000841
	(0.00178)	(0.00200)	(0.00175)
T-1	-0.000565	0.000166	-0.00168
	(0.00185)	(0.00202)	(0.00183)
T-2	0.000284	-0.000905	-0.00270**
	(0.00169)	(0.00142)	(0.00131)
T-3	0.00502***	-0.00378**	-0.000928
	(0.00161)	(0.00155)	(0.00139)
T-4	0.000265	-0.00306**	-0.00226
	(0.00154)	(0.00138)	(0.00163)
Observations	1,726	2,539	2,040
R-squared	0.073	0.030	0.052
Exposure	Region	Region	Region
Month FE:	X	X	X
Year FE:	X	X	X
Region FE:	X	X	X
Lagged Temp & Precip Controls	X	X	X
Household/Mother Controls	X	X	X
Standard Errors Clustered at the Region by Survey Year Level	X	X	X

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1, lags 4-8 left out of regression table

TABLE 8

Main Specification Stratified by Different Levels of Mother's Education (Quarterly)

	(1)	(2)	(3)
	Primary Completion or Less	Completion of grade somewhere in secondary range	Higher Education
VARIABLES	Birth Weight	Birth Weight	Birth Weight
Maximum Wind Speed	**-13.82*** **	1.985	4.369*
	(3.992)	(2.245)	(2.259)
T-1	0.871	-3.987	1.131
	(3.396)	(2.905)	(2.143)
T-2	-0.312	0.874	1.131
	(3.396)	(3.378)	(2.742)
T-3	3.182	-5.052	9.410**
	(5.606)	(3.157)	(4.131)
Observations	1,726	2,539	2,040
R-squared	0.083	0.042	0.063
Exposure	Region	Region	Region
Month FE:	X	X	X
Year FE:	X	X	X
Region FE:	X	X	X
Lagged Temp & Precip Controls	X	X	X
Household/Mother Controls	X	X	X
Standard Errors Clustered at the Region by Survey Year Level	X	X	X

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1, lags 4-8 left out of regression table

TABLE 9

Main Specification Stratified into Mother's Education Level

	(1)	(2)	(3)
	Primary Completion or Less	Completion of grade somewhere in secondary range	Higher Education
VARIABLES	Probability of Low Birth Weight	Probability of Low Birth Weight	Probability of Low Birth Weight
Maximum Wind Speed	**0.00568*** **	-0.00154	-0.000890
	(0.00210)	(0.00120)	(0.00120)
T-1	0.000339	0.00146	-0.00304**
	(0.00188)	(0.00173)	(0.00126)
T-2	0.00155	-0.000609	0.00206
	(0.00226)	(0.00180)	(0.00144)
T-3	0.000504	0.00222	-0.00374**
	(0.00313)	(0.00211)	(0.00168)
Observations	1,726	2,539	2,040
R-squared	0.085	0.032	0.054
Exposure	Region	Region	Region
Month FE:	X	X	X
Year FE:	X	X	X
Region FE:	X	X	X
Lagged Temp & Precip Controls	X	X	X
Household/Mother Controls	X	X	X
Standard Errors Clustered at the Region by Survey Year Level	X	X	X

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1, lags 4-8 left out of regression table

TABLE 10

Main Specification Divided into Female/Male and Rural/Urban (Quarterly)

	(1)	(2)	(3)	(4)
	Female	Male	Rural	Urban
	Birth Weight	Birth Weight	Birth Weight	Birth Weight
Maximum Wind Speed	-0.215	-1.394	-0.214	-1.073
	(2.472)	(2.151)	(2.492)	(2.005)
T-1	1.843	-2.809	-2.323	0.884
	(2.102)	(1.972)	(1.913)	(1.992)
T-2	**-5.545***	4.005	0.671	-1.025
	(2.839)	(2.494)	(2.873)	(2.518)
T-3	6.516**	-0.781	-0.317	5.579**
	(3.242)	(2.476)	(2.632)	(2.76)
Observations	2,961	3,344	3,290	3,015
R-squared	0.041	0.047	0.041	0.041
Exposure	Region	Region	Region	Region
Month FE:	X	X	X	X
Year FE:	X	X	X	X
Region FE:	X	X	X	X
Lagged Temp & Precip Controls	X	X	X	X
Household/Mother Controls	X	X	X	X
Standard Errors Clustered at the Region by Survey Year Level	X	X	X	X

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1, lags 4-8 left out of regression table

TABLE 11

Probability of Low Birth Weight Stratified by Gender and Rural or Urban (Quarterly)

	(1)	(2)	(3)	(4)
	Female	Male	Rural	Urban
VARIABLES	Probability of Low Birth Weight	Probability of Low Birth Weight	Probability of Low Birth Weight	Probability of Low Birth Weight
Maximum Wind Speed	-0.000404	0.00119	0.000449	0.000335
	-0.00113	-0.000951	-0.00138	-0.00101
T-1	-0.00117	-0.000627	-0.000268	-0.00132
	-0.00133	-0.00124	-0.00112	-0.00106
T-2	0.00172	-0.000762	0.00114	-0.000651
	-0.00164	-0.00135	-0.00171	-0.00101
T-3	-5.45E-05	-0.000907	-0.00133	0.000202
	-0.00204	-0.00129	-0.00167	-0.00125
Observations	2,961	3,344	3,290	3,015
R-squared	0.03	0.034	0.036	0.028
Exposure	Region	Region	Region	Region
Month FE:	X	X	X	X
Year FE:	X	X	X	X
Region FE:	X	X	X	X
Lagged Temp & Precip Controls	X	X	X	X
Household/Mother Controls	X	X	X	X
Standard Errors Clustered at the Region by Survey Year Level	X	X	X	X

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1, lags 4-8 left out of regression table

FIGURE 1

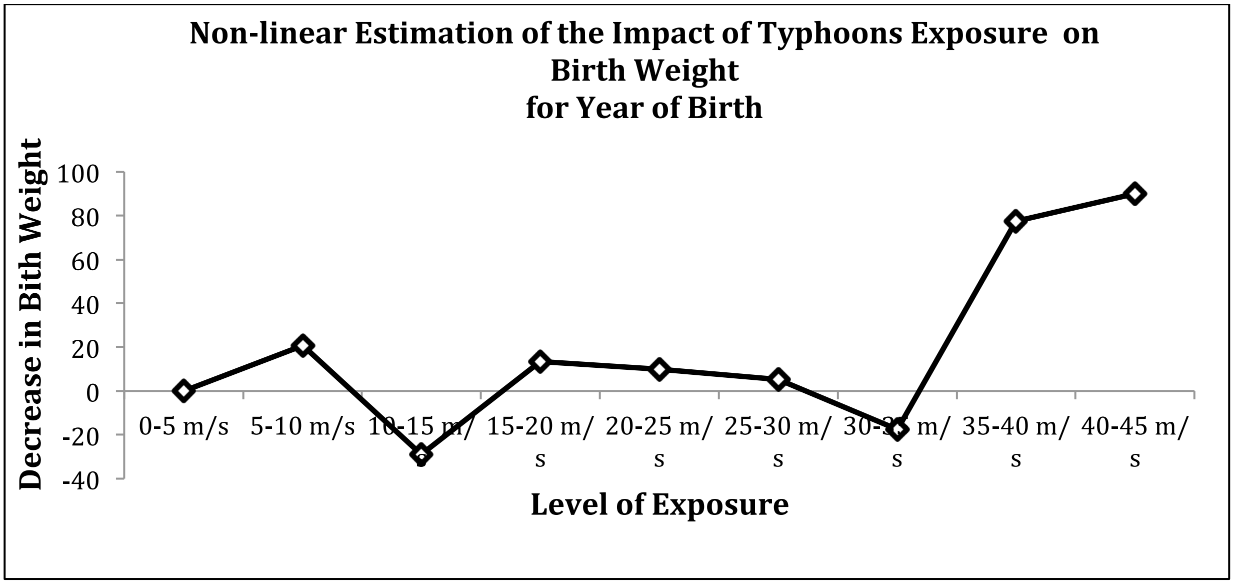

FIGURE 2

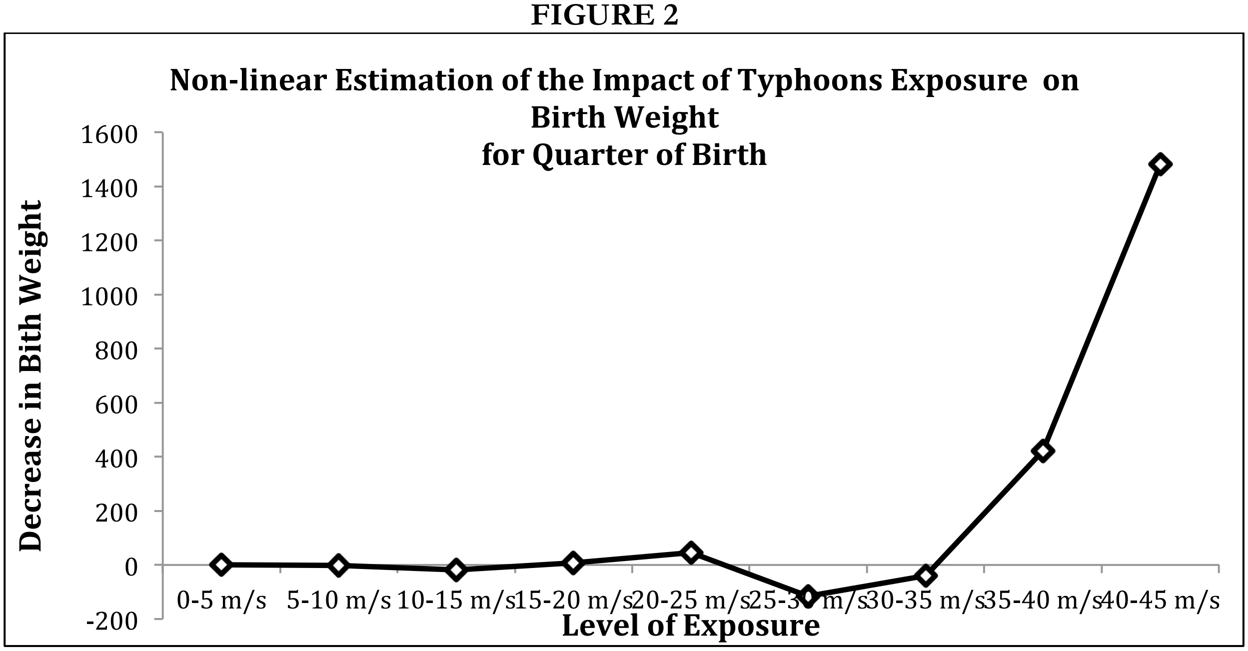

TABLE 12

Robustness Check (mother years resident >5): for the Main Specification by different levels of mother's education (Quarterly)

	(1)	(2)	(3)
	Primary Completion or Less	Completion of grade somewhere in secondary range	Higher Education
VARIABLES	Birth Weight	Birth Weight	Birth Weight
Maximum Wind Speed	**-6.364****	-0.219	2.107
	(2.614)	(1.744)	(1.745)
T-1	2.833	-2.172	0.926
	(2.940)	(1.741)	(1.684)
T-2	-1.867	0.0368	-1.459
	(2.537)	(1.800)	(1.879)
T-3	1.732	-2.630	6.155*
	(2.433)	(2.177)	(3.084)
Observations	3,562	5,602	4,015
R-squared	0.056	0.026	0.032
Exposure	Region	Region	Region
Month FE	X	X	X
Year FE:	X	X	X
Region FE:	X	X	X
Lagged Temp & Precip Controls	X	X	X
Household/Mother Controls	X	X	X
Standard Errors Clustered at the Region by Survey Year Level	X	X	X

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1, lags 4-8 left out of regression table

TABLE 13

Robustness Check (mother's years resident >5): Main Specification by different levels of mother's education (quarterly)

	(1)	(2)	(3)
	Primary Completion or Less	Completion of grade somewhere in secondary range	Higher Education
VARIABLES	Probability of Low Birth Weight	Probability of Low Birth Weight	Probability of Low Birth Weight
Maximum Wind Speed	0.00183	2.17e-05	0.000132
	(0.00137)	(0.000963)	(0.000910)
T-1	-0.000648	0.000401	-0.00206*
	(0.00110)	(0.00106)	(0.00109)
T-2	0.00109	-4.51e-05	0.00158
	(0.00167)	(0.00109)	(0.00100)
T-3	0.00110	0.00124	-0.00116
	(0.00146)	(0.00147)	(0.00134)
Observations	3,562	5,602	4,015
R-squared	0.055	0.019	0.026
Exposure	Region	Region	Region
Year FE:	X	X	X
Region FE:	X	X	X
Lagged Temp & Precip Controls	X	X	X
Household/Mother Controls	X	X	X
Standard Errors Clustered at the Region by Survey Year Level	X	X	X

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1, lags 4-8 left out of regression table

TABLE 14

Robustness check: Full sample with Education*New_Maxs interaction term

	(1)	(2)	(3)
VARIABLES	Birth Weight	Birth Weight	Birth Weight
Maximum Wind Speed	1.743	-2.704*	-2.560
	(1.742)	(1.556)	(2.007)
T-1	-0.717	-0.450	-0.646
	(1.516)	(1.525)	(1.509)
T-2	-0.111	-0.174	-0.0158
	(1.851)	(1.869)	(1.846)
T-3	2.478	2.541	2.464
	(1.833)	(1.853)	(1.812)
Mother's Education Primary or Lower	-6.670		
	(27.88)		
Primary*New_Maxs	**-11.14*** **		
	(3.242)		
Mother's Education in Secondary Range		-2.399	
		(23.21)	
Secondary*New_maxs		4.055*	
		(2.189)	
Mother's Education Greater than Secondary			8.375
			(26.20)
Higher*New_maxs			4.900*
			(2.710)
Observations	6,305	6,305	6,305
R-squared	0.034	0.031	0.031
Exposure	Region	Region	Region
Month FE:	X	X	X
Year FE:	X	X	X
Region FE:	X	X	X
Lagged Temp & Precip Controls	X	X	X
Household/Mother Controls	X	X	X
Standard Errors Clustered at the Region by Survey Year Level	X	X	X

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1, lags 4-8 left out of regression table

TABLE 15

Main Specification by different levels of mother's education with interaction(quarterly)

	(1)	(2)	(3)
VARIABLES	Child Low Birth Weight	Child Low Birth Weight	Child Low Birth Weight
Maximum Wind Speed	-0.000956	0.00202**	0.000812
	(0.000707)	(0.000838)	(0.000988)
T-1	-0.000510	-0.000675	-0.000599
	(0.000872)	(0.000870)	(0.000895)
T-2	0.000759	0.000780	0.000707
	(0.00107)	(0.00108)	(0.00106)
T-3	-0.000208	-0.000251	-0.000239
	(0.00104)	(0.00106)	(0.00105)
Primary Education	0.0262		
	(0.0158)		
Primary* New_maxs	**0.00595*** **		
	(0.00190)		
Mother's Education in Secondary Range		0.00369	
		(0.0131)	
Secondary*New_maxs		-0.00354***	
		(0.00123)	
Mother's Education Higher than Secondary			-0.0272*
			(0.0142)
Higher*New_maxs			-0.00104
			(0.00130)
Constant	0.432	0.498	0.445
	(0.957)	(0.960)	(0.960)
Observations	6,305	6,305	6,305
R-squared	0.030	0.027	0.027
Exposure	Region	Region	Region
Month FE	X	X	
Year FE:	X	X	X
Region FE:	X	X	X
Lagged Temp & Precip Controls	X	X	X
Household/Mother Controls	X	X	X
Standard Errors Clustered at the Region by Survey Year Level	X	X	X

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1, lags 4-8 left out of regression table

TABLE 16

Main Specification Divided by Mother's level of education with Mother's Fixed Effects

	(1)	(2)	(3)	(4)
	Main Specification	Primary Completion or Less	Completion of grade somewhere in secondary range	Higher Education
VARIABLES	Birth Weight	Birth Weight	Birth Weight	Birth Weight
Maximum Wind Speed	-3.836	-12.89	-1.754	-1.474
	(4.212)	(9.687)	(6.504)	(7.796)
T-1	-2.941	-8.167	-5.968	1.343
	(4.304)	(8.613)	(8.478)	(5.956)
T-2	0.825	0.372	4.428	-1.773
	(4.234)	(7.146)	(7.772)	(5.720)
T-3	-1.705	-1.035	-9.462	3.157
	(5.701)	(12.66)	(9.613)	(6.966)
Exposure	Region	Region	Region	Region
Mother FE:	X	X	X	X
Region FE:	X	X		X
Lagged Temp & Precip Controls	X	X	X	X
Household/Mother Controls	X	X	X	X
Standard Errors Clustered at the Region by Survey Year Level	X	X	X	X

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1, lags 4-8 left out of regression table

TABLE 17

Main Specification Divided by Mother's level of education with Cluster Fixed Effects

	(1)	(2)	(3)	(4)
	Main Specification	Primary Completion or Less	Completion of grade somewhere in secondary range	Higher Education
VARIABLES	Birth Weight	Birth Weight	Birth Weight	Birth Weight
Maximum Wind Speed	-0.789	-9.598**	1.927	3.604
	(1.915)	(4.351)	(2.867)	(3.628)
T-1	-1.261	-4.374	-3.590	2.131
	(1.618)	(4.368)	(3.681)	(3.443)
T-2	1.403	0.234	-3.605	1.277
	(2.140)	(4.448)	(4.507)	(3.161)
T-3	1.248	7.504	-6.887	5.005
	(2.018)	(5.882)	(4.534)	(4.598)
Observations	6,305	1,726	2,539	2,040
R-squared	0.224	0.503	0.395	0.454
Exposure	Region	Region	Region	Region
Cluster FE:	X	X	X	X
Region FE:	X	X		X
Lagged Temp & Precip Controls	X	X	X	X
Household/Mother Controls	X	X	X	X
Standard Errors Clustered at the Region by Survey Year Level	X	X	X	X

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1, lags 4-8 left out of regression table