Selective mortality and the long-term effects of early-life exposure to natural disasters*

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Abstract

We analyze the effects of early-life shocks with varying degrees of severity on mortality and human capital outcomes in the Philippines. We exploit variations in typhoon exposure and the introduction of a short-term post-disaster relief policy. Severe typhoons are associated with increased mortality and adverse long-term outcomes. Before the disaster relief policy, mortality from in utero exposure to severe typhoons was 10 percent, and survivors exhibited similar levels of human capital as the unaffected. Once implemented, the policy appears to have mitigated the mortality effect of severe typhoons, and survivors have lower human capital in the long term.

Keywords: fetal origins hypothesis, selective mortality, long-term outcomes, Philippines, natural disasters, disaster relief

JEL codes: I12, I15, O15

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1 Introduction

Environmental shocks often have lasting consequences on human capital development. Early-life exposure to negative environmental shocks may increase mortality (Doocy et al., 2007; Jayachandran, 2009) and have negative effects on human capital that persist into adulthood (Almond and Currie, 2011; Currie and Vogl, 2013). Additionally, climate change is expected to intensify the frequency and unpredictability of environmental shocks. Much of the existing literature focuses on the effects of rare and severe natural disasters. However, the question remains: with repeated environmental shocks, how do the effects vary by severity and frequency? A better understanding of the impacts directly relates to several policy concerns, such as investments on disaster preparedness and the provision of post-disaster aid.

In this paper, we examine the effects of early-life exposure to environmental shocks of varying intensity on human capital outcomes in a developing country, where geography and poverty present unique challenges. Environmental shocks occur more frequently in developing than in high-income countries (Hsiang and Jina, 2014), and the adverse effects of such shocks may be more pronounced in developing countries (Currie and Vogl, 2013; Hanna and Oliva, 2016; Arceo et al., 2016). Moreover, studies on developing countries are often plagued by the paradox of mortality selection: if the strong are more likely to survive, higher mortality rates could correspond to better adult outcomes among the positively selected survivors (Deaton, 2007; Bozzoli, Deaton, and Quintana-Domeque, 2009). Hence, if an early-life shock leads to higher mortality, its long-term effects on human capital may not be observed (Currie and Vogl, 2013; Meng and Qian, 2009). We analyze changes in both mortality and observed long-term outcomes after the introduction of a post-disaster relief policy. Using this policy change, we illustrate the challenge in evaluating the effectiveness of post-disaster aid due to the paradox of mortality selection.

Specifically, we use the unpredictability of severe tropical cyclones – typhoons – in the Philippines as a natural experiment to examine the persistent effects of early-life typhoon exposure. The Philippines is prone to typhoons: on average, five to six typhoons make landfall every year, one of which is a severe typhoon (Saffir-Simpson scale 4 or 5).[1] Despite the high frequency of natural disasters in the Philippines, disaster relief funds were virtually non-existent before Ferdinand Marcos came to power in 1965. The Marcos regime introduced various measures to increase funding for short-term disaster relief, which aimed to protect the affected population from some of the immediate deleterious effects of natural disasters. If the relief efforts implemented during Marcos' regime reduced typhoon-induced early-life mortality, we may observe changes in the long-term scarring among survivors. We find

[1] Author's calculations based on tropical cyclone data from 1945 to 2015.

evidence consistent with the hypothesis that the post-disaster funding protected exposed children from mortality, and the lower mortality, in turn, changed the survivors' observed long-term human capital outcomes.

Our empirical strategy exploits variations in the timing, geographic path, and intensity of typhoons in the Philippines. The high degree of similarity among different typhoon occurrences allows us to estimate the dose-response effects of early-life shocks by comparing the effects of a severe (Saffir-Simpson scale 4 or 5) typhoon to those of a less intense (Saffir-Simpson scale 1, 2, or 3) one. We employ a difference-in-differences method to analyze the effects of in utero and post-natal exposure to severe and less intense typhoons. We then separate early-life typhoon exposure into two periods: before and after Marcos assumed office in December 1965 to examine the post-disaster relief policy. Crucially, the 1990 Philippine Census recorded individuals' year and municipality of birth, which allows us to match each individual with the typhoon activities in his/her municipality of birth while he/she was in utero and in his/her first two years of life. We combine data from the 1990 Census and historical data on the intensity and paths of all tropical storms passing through the Philippines from 1945 to 1990. To analyze the effects on mortality, we use cohort size and the fraction of males in each cohort as proxies for mortality. To study the effects on long-term human capital accumulation, we use educational attainment and occupation in 1990 as outcome variables.

We find strong dose-response effects: large negative effects from severe typhoons, but not from less intense typhoons. In utero exposure to severe typhoons is associated with a 7 percentage point reduction in male cohort size and a lower fraction of males. These results are consistent with the fragile male hypothesis, which argues that males are more vulnerable to negative early-life shocks than females (Kraemer, 2000; Mathews et al., 2005). The large reduction in male cohort size, but small effects on female cohort size confirms that the reduction in cohort size is driven by an increase in early-life mortality rather than a decline in fertility. Less intense typhoons had little effect on either cohort size or the fraction of males. We then analyze the effects of early life exposure to typhoons on survivors' educational and labor market outcomes and find that only severe typhoons are associated with substantial adverse outcomes.

We also find changes in both mortality and the long-term effects on survivors after the Marcos regime came to power. The Marcos regime introduced various policy changes, most notably the short-term disaster relief policy. Before the Marcos regime, in utero exposure to severe typhoons reduced cohort size by almost 10 percentage points but had little impact on long-term outcomes – the surviving cohorts on average exhibited similar human capital outcomes as the unaffected cohorts. In contrast, under the Marcos regime, when disaster relief funds became more available, albeit still limited, in utero exposure to severe typhoons had little impact on mortality, but significantly reduced survivors' educational attainment and occupational skill level – 0.3 fewer years of education (with larger effects on males) and a 15 percentage point lower probability of attaining a skilled occupation. These findings suggest that the post-disaster relief efforts provided the social protection necessary to mitigate the adverse effects on early-life mortality, but were not sufficient to alleviate the long-term scarring effects. Under the Marcos regime, some individuals who would have died survived and adverse long-term effects are observed in these individuals. In other words, deteriorating long-term outcomes after the introduction of disaster relief policy actually reflect improved chances of survival.

The adverse long-term effects are intensified when we compare siblings within the same household. The estimates with household fixed effects are larger in magnitude than the difference-in-differences estimates with municipality fixed effects. This suggests that post-natal parental investments may reinforce the differences between siblings caused by the negative pre-natal shocks, which is consistent with the findings in Almond et al. (2009). We also examine heterogeneity in the long-term effects by family socioeconomic status (SES). The adverse effects are more pronounced on low-SES families than on high-SES families, suggesting that family resources affect their ability to cope with the aftermath of a severe typhoon and engage in compensating behavior for the affected children.

The remainder of the paper is organized as follows. Section 2 describes typhoons, disaster relief policy, and earlier literature on early-life shocks. Section 3 describes the data. Section 4 describes the estimation strategy and results. Section 5 concludes with policy implications.

2 Background and Literature Review

2.1 Typhoons in the Philippines

The Philippines is the fourth most disaster-prone country in the world.[2] Given its location in the western Pacific Ocean, the Philippines is the largest country to be exposed to typhoons on a regular basis – on average five to six typhoons make landfall in the country annually (Table 1), with an even larger number entering Philippine waters. Typhoons form all year round, the peak months being July to October.

The country comprises about 7,000 islands, which are categorized into the following island groups to reflect differences in both geographic location and economic development: Northern Luzon, Southern Luzon, Visayas, and Mindanao.[3] These island groups are administratively

[2]Source: UN, The Human Cost of Weather Related Disasters 1995-2015. URL (last accessed December 27, 2017): http://www.unisdr.org/2015/docs/climatechange/COP21_WeatherDisastersReport_2015_FINAL.pdf

[3]We divide the Luzon island groups into two parts to separate the predominantly agricultural north from

further divided into provinces and municipalities. The northeastern parts of the country, Northern Luzon and the eastern parts of Southern Luzon and the Visayas, are especially prone to typhoons.[4] However, most municipalities in the Philippines are prone to natural disasters such as earthquakes and volcanic eruptions. Hence, despite the high prevalence of migration in the Philippines, it is uncommon for citizens to migrate within the Philippines to avoid natural disasters, including typhoons.

Due to the country's familiarity with typhoons, institutions and infrastructure in the Philippines are more prepared to cope with typhoons than in other developing countries. Despite this familiarity, severe typhoons may still cause extensive damages. For example, Franklin and Labonne (2017) show that local labor markets in the Philippines are unaffected by low-intensity typhoons, but substantially disrupted by severe ones. We analyze the effect of storms of varying severity on mortality and long-term human capital outcomes.

2.2 Disaster relief before and under the Marcos regime

Ferdinand Marcos rose to power in December 1965. Disaster preparedness gained prominence during the Marcos years. Previously, it had fallen under the National Civil Defense Administration established by the 1954 Civil Defense Act. The body was tasked with protecting the welfare of the population during national emergencies, including wars and typhoons.[5] However, the planning body was poorly funded and uninterested in disaster preparedness. This apathy changed abruptly after the Casiguran earthquake in August 1968. The 7.6 magnitude earthquake killed at least 207 people, most of whom died in Manila. Following this disaster, Marcos issued Administrative Order No. 151 in December 1968 and the National Committee on Disaster Operation was created.[6] This instigated the coordination of disaster response and disaster relief funding across different agencies. The committee issued a standard operating procedure that prescribed the organizational set-up for disasters from the national level down to the municipal level.

Post-disaster efforts focused on short-term assistance, such as clothing, food, and medicine after the disasters to mitigate immediate adverse outcomes such as disease outbreaks – one

the more industrialized south. They experienced divergent population growth trends during the period we study. Our definition of Northern Luzon includes Ilocos Region, Cordillera Administrative Region, Cagayan Valley, and Central Luzon. Southern Luzon includes NCR (Metro Manila), Southern Tagalog (Calabarzon and Mimaropa), and Bicol Region.

[4]Source: http://vm.observatory.ph/hazard.html (Last accessed December 27, 2017.)

[5]Source: NDCC, History of Disaster Management in the Philippines, URL (last accessed December 27, 2017): http://www2.wpro.who.int/internet/files/eha/tookit_health_cluster/History%20of%20Disaster%20Management%20

[6]Post-disaster relief efforts were further strengthened in the next decade. The disaster management plan was augmented after typhoon Sening (Joan), which struck in October 1970 and heavily affected the Metro Manila area. Marcos approved a Disaster and Calamities Plan, which led to the creation of a National Disaster Control Center (NDCC). The NDCC includes almost all Department Secretaries as members and still serves as the most important policy-making agency for disasters in the Philippines.

potential cause of child mortality in this context. Key stakeholders, including the military, were mobilized to provide disaster relief and to maintain the stability of prices of prime commodities such as rice, the main staple. Marcos also tapped foreign assistance to provide relief goods after major typhoons and personally directed the relief effort, involving his wife and son in some cases. There is evidence that these disaster relief efforts were part of the regime's political manipulation in so far as they gave preferential treatment to their supporters (Warren, 2013). Nonetheless, on average, the availability of post-disaster assistance may mitigate the short-term deleterious effects of negative shocks, such as early-life mortality. To our knowledge, there is no detailed record of how much and where resources were sent after each disaster during the Marcos regime. Therefore, we unfortunately cannot exploit regional variations in post-disaster relief to evaluate the per capita effect of relief spending. Instead, we assess the overall effectiveness of post-disaster relief policies by estimating the average changes in typhoon-induced mortality and long-term effects after the introduction of such policies.

2.3 The effects of early-life shocks

Research has shown that negative early-life shocks can affect mortality and have persistent impacts on survivors' later life outcomes (Almond and Currie, 2011; Currie and Vogl, 2013). Children in utero are especially vulnerable because their fetal programming may be altered by negative shocks, leaving them susceptible to poor well-being in adulthood (Barker, 1995).

The competing effects of culling and scarring affect the observed long-term effects among survivors. When the effect of culling dominates, we may observe no scarring because survivors are highly positively selected (Kannisto et al., 1997). Evidence from birth cohort data demonstrates that, in high mortality settings, declines in child mortality are associated with decreased height, but in settings with limited selective mortality, declines in child mortality are associated with increased height, and, in turn, height correlates with skill (Deaton, 2007; Bozzoli, Deaton, and Quintana-Domeque, 2009). With low selective mortality, scarring among survivors may be more pronounced, such as the case of the 1918 flu pandemic (Almond, 2006; Lin and Liu, 2014). This paper builds on Bozzoli, Deaton, and Quintana-Domeque (2009) and illustrates the competing effects of culling and scarring in a within-country setting where a major policy change led to variations in mortality selection.

Negative shocks early in life lower children's human capital endowment. This makes later life investments difficult, leading to poor human capital outcomes in adulthood (Cunha and Heckman, 2007). However, it is possible that mediation occurs to mitigate the initial effects of negative shocks. Conditional on survival, early interventions may offer protective effects if they have occurred in the critical period of development (Currie and Almond, 2011;

Almond and Mazumder, 2013). They may allow affected children to catch up (Aguilar and Vicarelli, 2011; Adhvaryu et al., 2015; Gunnsteinsson et al., 2016). By analyzing the effects of the disaster relief policy, we also extend the literature on the mitigating effects of early-life interventions (Almond et al., 2017).

By using typhoons as natural experiments, we build on a growing body of literature that uses natural experiments as a source of exogenous variation to identify the persistent effects of early-life shocks (Almond and Currie, 2011; Maccini and Yang, 2009; Currie and Rossin-Slater, 2013; Shah and Steinberg, 2017). We also add to a growing body of research on the effects of typhoons in the Philippines. Ugaz and Zanolini (2011) find significant reductions in the height of children who were exposed to severe typhoons while in utero. Deuchert and Felfe (2015) and Anttila-Hughes and Hsiang (2013) suggest substantial reductions in household assets and expenditure in the years after a typhoon occurrence, which lead to reductions in children's educational attainment (Deuchert and Felfe, 2015) and increases in infant mortality rates (Anttila-Hughes and Hsiang, 2013). Compared to these earlier studies, our use of multiple typhoons in a generalized difference-in-differences framework allows us to compare the effects of in utero exposure relative to exposure at other ages. We do not exclude the possibility that typhoon exposure adversely affects children of all ages, perhaps through reductions in household wealth and expenditure. Rather, we focus on the incremental effects of in utero exposure – the difference between the effects on cohorts who were exposed in utero and cohorts who were exposed at other stages of life. Other than reduced income and expenditure, poor maternal nutrition and sustained maternal stress could also lead to adverse long-term effects (Liu et al., 2016).

3 Data

We draw our outcome variables from the Philippine Census of Population and Housing 1990 (hereafter, CPH 1990). We match each individual in CPH 1990 with historical typhoon exposure information in his or her municipality of birth. To measure typhoon exposure and intensity, we use the best-track data from the Japan Meteorological Agency Tropical Cyclone Database (henceforth, JMA) and the typhoon analogs (TD-9635) collected by the National Climatic Data Center.

3.1 Typhoon Data

The JMA provides the most reliable information of all tropical storms passing the Western North Pacific (WP) basin. For each tropical storm between 1951 and 1990, JMA records the longitude and latitude of the storm center and the minimum central pressure every six hours.[7] The typhoon analogs (TD-9635), collected by the National Climatic Data Center, provide the same information for typhoons that passed through the WP basin between 1945 and 1950.

We use the coordinates of the storm center to identify affected municipalities. First, we generate best-fit lines through the six-hourly observations to identify the storm path. Then, we calculate the distance between the centroid of the municipality and the storm path for each municipality-storm pair. If the distance is within 30 kilometers (km), we treat the municipality as affected by the storm.[8]

To measure storm intensity, we use the minimum central pressure (MCP).[9] The intensity of a storm fluctuates as the storm proceeds, but our databases provide MCP measures only every six hours. To measure the storm intensity for each of the affected municipalities, we use the weighted average of the MCP readings of the two nearest observation points, using the inverse distance between the observation and the municipality as weights. We then categorize typhoon intensity according to the Saffir-Simpson scale[10], and generate an indicator for "small typhoon" if the storm is of category 3 or lower and "severe typhoon" if the storm is of category 4 or 5 when the storm reached the municipality.

Storm path and severity vary considerably across the island groups. For example, Figure A.1 shows the paths and severity of all typhoons that passed the Philippines in 1970. Table 1 shows the number of typhoons per municipality-year by the four island groups. We separate the sample into two periods: pre-1965 and post-1965. On average, the number of small typhoons is similar across the two time periods. However, severe typhoons are more frequent in the post-1965 period, especially in the Luzon island groups.

[7] Links to both data sets can be found on the IBTrACS webpage, URL (last accessed December 27, 2017) https://www.ncdc.noaa.gov/ibtracs/index.php?name=rsmc-data

[8] For robustness, we use a distance of 60 kilometers from the storm center to define affected municipalities. We also use the nearest distance between the municipality and the storm track to measure municipality-to-storm distance. The results are qualitatively similar.

[9] We use the MCP instead of the more commonly used maximum sustained wind speed (MSW) due to data limitations. MSW was not available in the JMA database until 1972; additionally, the MSW calculation was revised in the 1980s to be consistent across meteorological agencies. When both MSW and MCP are available in the JMA database, the two measures are highly correlated (-0.833, p-value $<$0.01). Moreover, recent meteorological studies found that due to changes in practice over time at meteorological agencies, records of MSWs for pre-1980s storms in the WP basin are likely to be of low quality (Knapp et al., 2013). Hence, MCP serves as a more accurate measure of storm intensity for pre-1980 tropical cyclones in the WP basin.

[10] A category 5 typhoon is one with MCP below 920 millibars; a category 4 typhoon is one with MCP between 920 and 944 millibars; category 3 is between 945 and 964 millibars; category 2 is between 965 and 979 millibars; category 1 is between 980 and 999 millibars. Storms with MCP at or above 1000 millibars are not considered typhoons.

3.2 Philippine Census Data

Outcome variables Our identification strategy requires us to link individuals' later life outcomes to typhoon exposure in utero and in his or her first two years of life. We use the CPH 1990 10% Household Sample because it is the only census sample that identifies the usual place of residence of each respondent's mother at the time of the respondent's birth. This longer census questionnaire was administered to approximately 10 percent of the population. Our outcomes of interest include cohort size as well as the education and labor market outcomes of individuals. We draw these variables from the census.

Ideally, detailed data on fetal, infant, child, and adult mortality rates would be available for each cohort born in a given municipality. Unfortunately, such mortality records, especially fetal mortality, do not exist for the Philippines. We follow Jayachandran (2009) and infer mortality by measuring cohort size in 1990 based on individuals' municipality of birth. As such, cohort size at birth is proxied by the probability of survival to May 1, 1990.[11]

Educational outcomes include literacy, high school completion, and years of education. The census does not include information on respondents' labor market earnings but provides detailed information on respondents' occupations. Based on each respondent's reported occupation, we construct three indicators of occupational skill level: whether the respondent has a skilled occupation, an associate professional occupation, or a professional occupation. The Data Appendix details the construction of cohort size at birth, years of education, and occupational skill level indicators.

Exposure variables To identify whether an individual was affected by typhoons in early-life, we link each respondent in CPH 1990 to the typhoon data according to the respondent's age and municipality of birth. Municipality of birth is given by the usual place of residence of the respondent's mother at the time of the respondent's birth.

Our main exposure variables are the expected number of small and severe typhoons that each respondent (or cohort) was exposed to during the in utero period and in the first two years of life.[12] We use this expected number of typhoons as our treatment variable because

[11]The reductions in observed cohort size is due to a combination of early-life (under the age of one) and later-life mortality. While the highest mortality is attributed to early-life deaths, later-life mortality may be a concern. To address this, we replicate our cohort size analysis using cohort size in the 1970 Census (CPH 1970). CPH 1970 allows us to restrict the sample to cohorts born before 1965 (aged between 5 and 23 in 1970), but CPH 1970 provides only the respondent's province of birth, not the municipality of birth. Hence, typhoon exposure is defined at the province level, which severely limits the accuracy of the estimates. Nonetheless, the results using CPH 1970 are similar in magnitude to our main results using CPH 1990.

[12]About 95% of siblings were born in the same municipality, so migration in early-life is low. Therefore, we expect measurement error in our exposure variable in the first two years of life to be small. We explore this further in the Appendix.

respondents' month of birth is unfortunately not available. However, we do observe each respondent's age as of May 1, 1990, as well as the exact date that the typhoons passed his or her municipality of birth. To construct the expected number of typhoon exposures, we assume that an individual of age y is equally likely to be born any day between May 2, $1990 - y - 1$, and May 1, $1990 - y$, and that gestation starts 40 weeks prior to the potential date of birth.[13] We then use the date that a typhoon passed the municipality of birth to construct the probability that the individual was exposed to the typhoon in utero. We also construct the probability of exposure in the first two years of life in a similar fashion. We sum the probabilities across typhoons to derive the expected number of typhoons that each respondent (or cohort) is exposed to at each stage of life. The Data Appendix details the construction of the exposure variables.

This measure allows us to fully exploit the temporal variations of typhoons. For example, because respondents' ages are recorded as of May 1, 1990, a typhoon that took place between August and October 1970 could potentially affect the in utero period of two cohorts – ages 18 and 19 – with a higher probability of affecting the 19-year-old cohort in utero than the 18-year-old cohort. In contrast, a typhoon that took place in May or June of 1970 could only possibly affect the in utero period of one age cohort – the 19-year-old cohort. These variations are fully captured by our exposure variable: expected number of typhoons, but would not be captured by a dummy variable indicating whether a typhoon took place one year before birth or the year of birth. The temporal dimension is especially important since most typhoons in the Philippines take place between June and November of each year.[14]

Sample restrictions Respondents in the Philippines should finish high school by the age of 16 and vocational college by the age of 18 if there is no grade repetition or late enrollment. We restrict the sample to respondents over the age of 18 to ensure that most would have entered the labor market by 1990.[15] As we are interested in typhoon exposure in the first 3 years after conception, we further restrict the sample to respondents between the ages of 18 and 43 (those born between 1947 and 1972) to ensure that we have each respondent's full

[13]We use 36 and 38 weeks of gestation as alternative specifications and find qualitatively similar results.

[14]We perform all our analysis with two sets of alternative typhoon exposure variables: (1) dummy variables indicating whether *any* small or severe typhoon passed the municipality of birth in the three years around birth, and (2) the *number* of small or severe typhoons that passed the municipality of birth in the three years around birth. Results using these alternative measures are consistent with our main findings (Section 4.5).

[15]The youngest cohorts may still be in tertiary education in 1990. To assess the extent of this concern, we use individuals' completed years of schooling in the 2000 Census of Population and Housing to infer the percentage of each cohort that would have completed schooling by 1990 if there had been no gaps or repetitions in their schooling. The data indicate that 86 percent of the 18-year-old cohort, 89 percent of the 19-year-old cohort, 94 percent of the 20 and 21-year-old cohorts, and 95 percent of the 22-year-old cohort would have completed schooling by 1990.

history of typhoon exposure in utero and in his first two years of life. [16]

4 Results

4.1 Estimation strategy

We exploit the temporal and geographical variation of the typhoon paths as well as exogenous variations in typhoon intensity. We employ a difference-in-differences method, exploiting variations at the cohort-municipality level. Specifically, we compare individuals who were exposed to typhoons either in utero or in their first two years of life to those who were either born in the same municipality in a different year or born in a different municipality in the same year and were, therefore, exposed neither in utero nor in the first two years of their lives.

Subsection 4.2 presents the results on mortality, using cohort size and the fraction of males in each cohort as outcome variables to infer mortality. Subsection 4.3 presents the results on long-term educational and occupational outcomes. In subsection 4.4, we extend our analysis to sibling comparisons. We compare individuals who were exposed to typhoons either in utero or in their first two years of life to a sibling who was born in a different year and, hence, never exposed during the early-life period.

4.2 Cohort size and mortality

We begin by analyzing the effects of early-life exposure to typhoons on mortality using cohort size and the fraction of males as outcome variables. The estimated effects capture the cumulative effects of typhoon exposure on fetal, infant, child, and adult mortality. We estimate the following equation for each birth-municipality m and birth-year t,

$$\begin{aligned}\ln(CohortSize_{mt}) = {} & \theta_0\ small\_inutero_{mt} + \theta_1\ small\_postnatal_{mt} \\ & + \beta_0\ severe\_inutero_{mt} + \beta_1\ severe\_postnatal_{mt} \\ & + \phi_m + \tau_t \times \psi_{island} + \gamma_{region} \times t + \epsilon_{mt} \qquad (1)\end{aligned}$$

where $CohortSize_{mt}$ refers to the number of individuals *born* in municipality m and year t who survived until May 1, 1990. The treatment variable *small_inutero* measures exposure

[16] Table A.1 shows the outcomes of interest for those who were exposed to typhoons in utero either before (Panel A) or after 1965 (Panel B). We divide the sample to those exposed in utero to small typhoons only (column 1), those ever exposed to severe typhoons (column 2), and those never exposed to any typhoons (column 3). Conditional on survival to adulthood, the educational and occupational outcomes for those who were exposed to severe typhoons *before 1965* are *higher* than those who were exposed to small typhoons or never exposed to typhoons (Table A.1). However, those who were exposed to severe typhoons *after 1965* have lower occupational status.

to small typhoons in utero, and *small_postnatal* measures exposure to small typhoons in the first two years of life; *severe_inutero* and *severe_postnatal* are the corresponding measures for severe typhoons.

In all subsequent analysis, we include municipality fixed effects, ϕ_m, to take into account non-time varying municipality characteristics. We also include birth-year by island group fixed effects, $\tau_t \times \psi_{island}$, to account for differences in education and economic development policies across the four island groups that may affect the outcome of interest. In addition, we include region-specific time trends, $\gamma_{region} \times t$, to allow for differential population growth trends in the thirteen regions.[17] Standard errors are clustered two-ways at both the municipality and the province-by-birth-year levels. Clustering by province-birth-year allows us to account for the spatial correlation across municipalities in the typhoon exposure measures.

One caveat of using cohort size to study mortality effects is that cohort size also reflects changes in conception rate. To address this concern, we also use the fraction of males in each cohort and each municipality of birth as an outcome variable. Under the fragile male hypothesis (Kraemer, 2000), males are more susceptible to fetal and infant mortality than females. Adverse early-life shocks would reduce the fraction of males. If, instead, the adverse shock reduces the rate of conception, we would expect similar reductions in the male and female cohort size and no change in the fraction of males. Therefore, reductions in the fraction of males would provide suggestive evidence that the changes in cohort size are likely to be attributable to changes in mortality, rather than changes in the conception rate.

Table 2 presents the results of estimating Equation 1. We restrict our sample to cohorts between ages 2 and 43 in columns 1 to 4.[18] In columns 5 to 8, we further restrict our sample to cohorts aged 18 to 43 to match the sample we use for education and occupational outcomes. We find that severe typhoons are associated with increased mortality, but small typhoons are not. On average, in utero exposure to a severe typhoon reduces cohort size by about 5 percent, but exposure to a small typhoon has no significant effect on cohort size (column 1). The estimated effect is similar, about 7 percent, when we restrict the sample to ages 18 to 43 (column 5). We find no significant effects on cohort size resulting from exposure to small or severe typhoons in the first two years of life. Our finding is consistent with the literature on the adverse effects of in utero exposure to severe negative shocks and suggests a strong dose-response effect to the severity of the shock.

[17] There are 13 regions in the Philippines across the 4 island groups in 1990: 3 in the Northern Luzon island group (Ilocos Region, Cagayan Valley, and Central Luzon), 3 in Southern Luzon (National Capital Region, Southern Tagalog, and Bicol), 3 in Visayas (Western Visayas, Central Visayas, and Eastern Visayas), and 4 in Mindanao (Western Mindanao, Northern Mindanao, Southern Mindanao, and Central Mindanao).

[18] We exclude cohorts aged below 2 or above 43 because we do not have information on typhoon exposure in early life for those cohorts.

In addition, consistent with the fragile male hypothesis (Kraemer, 2000) and earlier empirical evidence (Mathews et al., 2005; Almond and Mazumder, 2011), the mortality effects of exposure to severe typhoons are more pronounced among males – the effect on male cohort size is large (8 percent) and statistically significant (column 2), whereas the effect on female cohort size is much smaller (3 percent) and statistically insignificant (column 3). The effects on the fraction of males (columns 4 and 8), albeit imprecisely estimated, indicate that exposure to a severe typhoon reduces the fraction of males in each cohort by 1 to 2 percentage points, suggesting that the reduction in male cohort size is driven by increases in early-life mortality rather than reductions in the conception rate.

We then examine the changes in mortality under the Marcos regime by separating typhoon exposures that occurred before and after Marcos assumed office in December 1965 and estimate the following equation:

$$\begin{aligned} \ln(CohortSize_{mt}) = &\ \rho_0\ pre\_65\_small\_inutero_{mt} + \rho_1\ pre\_65\_small\_postnatal_{mt} \\ &+ \alpha_0\ pre\_65\_severe\_inutero_{mt} + \alpha_1\ pre\_65\_severe\_postnatal_{mt} \\ &+ \theta_0\ post\_65\_small\_inutero_{mt} + \theta_1\ post\_65\_small\_postnatal_{mt} \\ &+ \beta_0\ post\_65\_severe\_inutero_{mt} + \beta_1\ post\_65\_severe\_postnatal_{mt} \\ &+ \phi_m + \tau_t \times \psi_{island} + \gamma_{region} \times t + \epsilon_{mt} \end{aligned} \quad (2)$$

where the treatment variables *small_inutero*, *small_postnatal*, *severe_inutero*, and *severe_postnatal* are interacted with either a *pre*_65 or a *post*_65 dummy variable indicating whether the typhoon exposure took place before or after December 1965. The implicit assumption is that all typhoons after December 1965 are covered by Marcos' disaster relief policies. We present the results using December 1968, the month that the National Committee on Disaster Operation was established, as the alternative cut-off in Subsection 4.5.

Table 3 presents the results of estimating Equation 2. The results show stark contrasts of mortality effects before and after 1965. In utero exposure to a severe *pre-1965* typhoon is associated with a statistically significant 10 percent decrease in overall cohort size in 1990 (column 1). This effect is stronger among males (14 percent) than among females (6 percent and not statistically significant). In contrast, the effects of in utero exposure to a severe *post-1965* typhoon are both substantively and statistically insignificant (columns 1-4). The estimates are similar when we restrict the sample size to cohorts between the ages of 18 and 43 (columns 5 to 8).[19] Although the effects on the fraction of males are imprecisely estimated,

[19] We restrict the sample to municipalities with at least one male and one female in each age cohort under 43 to ensure a balanced panel for all four outcome variables. Appendix Table A.3 presents results including all municipalities. The results are qualitatively similar.

the difference in magnitude is large between pre- and post- 1965 severe typhoons – in utero exposure to a severe *pre-1965* typhoon reduces the fraction of males by 2.2 percentage points, whereas a severe *post-1965* typhoon reduces the fraction of males by 0.6 percentage points (columns 4 and 8). Similar to our earlier findings, the effects of in utero exposure to a small typhoon are insignificant in magnitude both before and after 1965. Exposure to small typhoons in one's first two years of life is associated with a small reduction in cohort size post-1965.[20] The effects of exposure to severe typhoons in one's *first two years of life* are neither statistically nor substantially significant in the two time periods.

We interpret these as suggestive evidence that the Marcos regime's post-disaster relief measures reduced the short-term adverse effects of typhoons. This change in early-life mortality could, in turn, affect the observed long-term effects on the survivors, which we turn to in the next subsection.

4.3 Educational attainment and occupational skill level

Conditional on survival, we estimate the long-term effects of exposure to small and severe typhoons. We estimate the following equation for individual i, born in municipality m and year t:

$$\begin{aligned} y_{imt} = &\rho_0 \; pre\_65\_small\_inutero_{mt} + \rho_1 \; pre\_65\_small\_postnatal_{mt} \\ &+ \alpha_0 \; pre\_65\_severe\_inutero_{mt} + \alpha_1 \; pre\_65\_severe\_postnatal_{mt} \\ &+ \theta_0 \; post\_65\_small\_inutero_{mt} + \theta_1 \; post\_65\_small\_postnatal_{mt} \\ &+ \beta_0 \; post\_65\_severe\_inutero_{mt} + \beta_1 \; post\_65\_severe\_postnatal_{mt} \\ &+ \delta X_{imt} + \phi_m + \tau_t \times \psi_{island} + \gamma_{region} \times t + \epsilon_{imt} \end{aligned} \tag{3}$$

where y_{imt} is the outcome of interest. We include the same set of typhoon exposure variables as in Equation 2, with the implicit assumption that once a municipality is exposed to a typhoon, everyone residing in the municipality is exposed. Additionally, we include a male indicator as a covariate (X_{imt}). When occupation is the outcome variable, we also include years of education as a covariate in some specifications. As in Equation 2, we include municipality fixed effects, ϕ_{muni}, birth-year-by-island-group fixed effects, $\tau_t \times \psi_{island}$, and region-specific time trends, $\gamma_{region} \times t$. Standard errors are clustered two-way at both the municipality and the province-by-birth-year levels. In addition, observations are weighted by the person weights provided in CPH 1990.

[20] We explore this further by analyzing the effects of each typhoon category (Table A.15).

Education Table 4 presents the effects of early-life exposure to typhoons on educational attainment. There is a strong dose-response relationship with the intensity of the typhoon as well as a sharp increase in the scarring effects after 1965. Exposure to *small* typhoons, both pre- and post-1965, had little effect on educational attainment.[21] In contrast, in utero exposure to *severe* typhoons is associated with adverse effects on all three outcomes. Moreover, the adverse effects of severe typhoons are substantially more pronounced post-1965 than pre-1965. In utero exposure to severe pre-1965 typhoons had little effect on the educational attainment of survivors, which is not surprising since they were associated with high mortality rates. In contrast, in utero exposure to a severe post-1965 typhoon reduces the probability of being literate by 0.771 percentage points (a 0.80 percent reduction from the mean), reduces completed years of education by 0.342 years (a 3.53 percent reduction from the mean), and reduces the probability of completing high school by 1.81 percentage points (a 3.49 percent reduction from the mean).[22] We find no significant effects on education among those exposed to typhoons in their first or second year of life.

Occupation Table 5 presents the effects on occupational skill level. Again, we observe a strong dose-response relationship by the intensity of the typhoon and a sharp increase in the scarring effects after 1965. Exposure to small typhoons, both pre- and post-1965, is associated with small positive gains in occupational skill level.[23] In contrast, in utero exposure to a severe *post-1965* typhoon reduces occupational skill level – it reduces the probability of attaining a skilled occupation by 15.9 percentage points, an associate professional occupation by 6.9 percentage points, and a professional occupation by 5.19 percentage points. We find that exposure to severe *post-1965* typhoons in the first two years of life is also associated with lower occupational skill level, although the magnitude is smaller than in utero exposure.

[21] The estimated effects of in utero exposure to *small,* pre-1965 typhoons are positive for all three outcome variables. Although it seems odd to find long-term positive effects associated with exposure to small typhoons, the magnitudes of the coefficients are small compared to the effects of severe typhoons. In addition, small, non-destructive typhoons may benefit agriculture and fishing by increasing rainfall, lowering temperatures, and raising the abundance and variety of fish in nearshore waters (Lam et al., 2012; Yu et al., 2013). If some small typhoons increase agricultural and fishing income without much damage to local infrastructure, they may improve mothers' and children's nutritional intake in the ensuing months and contribute to positive long-term human capital outcomes. Appendix Table A.16 confirm that these positive effects stem from the lowest category (SS scale 1) typhoons, which are relatively common and non-destructive in the Philippines.

[22] Appendix Table A.4 shows the corresponding effects on education pooling all cohorts together. Exposure to small typhoons has no significant effect on educational outcomes, but exposure to severe typhoons is associated with adverse later life outcomes. On average, in utero exposure to one severe typhoon lowers educational attainment by 0.178 years and such exposure in the first two years of life reduces educational attainment by 0.059 years.

[23] Please refer to footnote 21 for an explanation of why small typhoons may have small positive effects. Exposure to severe typhoons is associated with lower occupational skill when we pool the cohorts (Table A.5).

The effects on labor market outcomes remain when we condition on years of completed education, which is similar to the US case (Karbownik and Wray, 2016). These findings suggest that scarring in the labor market operates through channels other than education, plausibly because educational attainment relies more on cognitive ability whereas labor market productivity relies on both cognitive ability and health. Interestingly, in utero exposure to severe, *pre-1965* typhoons is associated with a small, but statistically significant increase in the probability of attaining an associate professional and professional occupation, suggesting that survivors are extremely positively selected in the pre-Marcos era.

Heterogeneity by gender We explore the heterogeneous effects by gender in Tables 6 and 7 to further explore the fragile male hypothesis (Kraemer, 2000). We find that exposure to severe typhoons has a larger effect on male mortality rates than on female mortality rates in both the pre- and post-1965 periods. If surviving individuals are positively selected, the fragile male hypothesis predicts that the long-term scarring effects are larger on males when mortality rates are low; however, we may see no differential long-term effects by gender, or even larger long-term effects on females when early-life mortality rates are much higher among males than among females.

Table 6 presents the heterogeneous effects on educational attainment.[24] Severe, pre-1965 typhoons had no statistically significant effect on literacy or years of education for either gender; males who were exposed to severe typhoons in utero were less likely to complete high school. Post-1965, when the effects on mortality were lower, the effects of in utero exposure to severe typhoons are larger on males than on females for all three educational outcomes (although not statistically significant for the probability of high school completion). These results are consistent with the fragile male hypothesis – when mortality rates are low, long-term scarring is more pronounced among males. Table 7 presents the heterogeneous effects on occupational skill levels. Before Marcos, the effect of in utero exposure to severe typhoons on occupational skill levels is not statistically significant for males and slightly positive for females. Under Marcos, the adverse effect of in utero exposure to severe typhoons is similar for males and females, with slightly larger effects on the probability that males obtain a skilled occupation and modestly larger effects on the probability that females obtain an associate professional or professional occupation.

[24] Tables A.6 and A.7 present the results without separating the pre and post-1965 exposure. Severe typhoons are associated with lower education and occupational skill level.

4.4 Sibling comparisons

We compare those who are exposed to typhoons to their siblings by restricting our sample to households with adult co-resident children. We extend the difference-in-differences framework to this sample using household fixed effects instead of municipality fixed effects. Within-household analysis adds to our study in three ways.

First, this approach controls for unobserved heterogeneity across households. If the unobserved characteristics of households residing in typhoon-exposed areas deteriorate over time, perhaps due to migration, then our identifying assumption would be violated and we may over-estimate the effects of typhoons, especially the post-1965 typhoons. Sibling comparisons address these concerns by controlling for heterogeneities across households.

Second, by comparing the results with household fixed-effects to the results with municipality fixed-effects, we can provide some evidence of post-natal parental investment behavior (Almond et al., 2009). If within-household sibling comparisons yield smaller effects than cross-household difference-in-differences analyses, parents may have compensated for the negative pre-natal shocks by investing more in the affected child after birth (or there may be changes over time in the unobserved heterogeneity of typhoon-exposed households). However, if within-household sibling comparisons yield larger effects than the cross-household analyses, it suggests that parents reinforce negative pre-natal shocks by investing less in the affected child post-natally.

Third, we further stratify our household sample by parental socioeconomic status to examine heterogeneities in the effects of typhoons since low-income households may be more vulnerable to typhoons. In the Philippines, low-income households are more likely to have houses that may be heavily damaged or destroyed by severe typhoons. High-income households are more likely to live in concrete buildings on higher ground, which may be less damaged or remain intact after a severe typhoon. Past research shows that typhoons are more damaging to low-income households' assets than those of high-income households (Anttila-Hughes and Hsiang, 2013; Deuchert and Felfe, 2015; Huigen and Jens, 2006), and wealthy, politically connected families may also be better able to obtain post-disaster funds (Atkinson et al., 2014). We, therefore, expect in utero typhoon exposure to be more damaging to children born to low-income families.

We now restrict our sample to households with adult co-resident children – individuals between the ages of 18 and 43 who reside in the same household as their parent(s) and whose reported relationship to the household head is either that of "son" or "daughter". We further restrict the sample to individuals with at least one other sibling living in the same household. These restrictions allow us to identify siblings and their parents, but also leave us with a selected sample.[25]

Tables 8 and 9 present the effects of early-life typhoon exposure on education and occupation, respectively, using the adult co-resident children sample. In both tables, columns 1 to 3 present sibling comparison results using household fixed effects. Because this co-resident sample is different from the full sample used in the main analysis, we repeat the difference-in-differences analysis with municipality fixed effects on this co-resident sample (columns 4 to 6) for ease of comparison. The basic patterns found in the cross section persist when we use household fixed effects. Moreover, comparing columns 1 to 3 to columns 4 to 6 in both tables shows that the negative effects of in utero exposure to severe typhoons are larger in magnitude when using household fixed effects than when using municipality fixed effects. This is true for both pre- and post-1965 typhoons. These reduced-form estimates offer suggestive evidence that post-natal parental investment may reinforce the differences between siblings caused by negative pre-natal shocks, but we cannot ascertain the channels through which parents invest differentially in children.

Next, we stratify our sample by household socioeconomic status. Ideally, we would use a measure of family income or wealth around the time of the child's birth as the yardstick to divide households into low and high-SES sub-samples. In the absence of a direct measure of past household income or wealth, we divide the sample according to whether the household head has a skilled occupation.[26] Tables 10 and 11 present the effects of early-life exposure to typhoons on education and occupational skill level by household SES. For both years of education and occupational status, the adverse effects are lower among affected children from high-SES households than those from low-SES households.

These reduced form estimates are consistent with two potential mechanisms that lie beyond the scope of this paper. One possibility is that high-SES families have more resources to cope with severe typhoons. Hence, the wealthier the family, the lower a typhoon's impact on the mother's psychological well-being and nutritional intake. Another possibility is that parents in high-SES families engage in post-natal compensating behavior – enhancing human capital investment in a child who experienced negative shocks in early life, whereas parents in low-SES families with limited resources adopt reinforcing behavior post-natally – reducing

[25] Respondents in this adult co-resident children sample are on average more educated than the overall population. Average education in the main analyzed sample is 9.4 years, compared to 10.5 years in the adult co-resident household sample. In addition,the fraction of the co-resident sibling sample who were ever exposed pre-1965 are higher than the fraction of the main sample. The post-1965 co-resident sibling sample is more comparable to the post-1965 sample in our main analysis.

[26] We choose this measure because the distribution of the household heads' occupation is relatively stable across age groups, whereas other variables such as years of education vary more by age group. Since household heads in the adult co-resident children sample are older (with an average of 54 years versus 44 years in the CPH1990), the household head's occupation provides a time-consistent way of defining household SES.

investment in a child who experienced negative shocks in early life.

4.5 Robustness

Effects by timing of exposure We conduct an event study analysis to show the effects of exposure to typhoons that took place before, during, and after the gestation period. To keep the model parsimonious, we include only severe typhoons in our analysis. We estimate the following equation:

$$\begin{aligned}\ln(cohort\ size_{mt}) = {} & \alpha_{-1}\ pre\_65\_severe_{m,t-3\ or\ t-2} + \alpha_0\ pre\_65\_severe_{m,t-1\ or\ t} \\ & + \alpha_1\ pre\_65\_severe_{m,t+1\ or\ t+2} + \alpha_2\ pre\_65\_severe_{m,t+3\ or\ t+4} \\ & + \beta_{-1}\ post\_65\_severe_{m,t-3\ or\ t-2} + \beta_0\ post\_65\_severe_{m,t-1\ or\ t} \\ & + \beta_1\ post\_65\_severe_{m,t+1\ or\ t+2} + \beta_2\ post\_65\_severe_{m,t+3\ or\ t+4} \\ & + \phi_m + \tau_t \times \psi_{island} + \gamma_{region} \times t + \epsilon_{mt} \qquad (4)\end{aligned}$$

where $pre\_65\_severe_{m,t-3\ or\ t-2}$ is a dummy variable indicating whether the birth-municipality, m, was exposed to any pre-1965 severe typhoons two to three years before the individual's birth-year, t; $pre\_65\_severe_{m,t-1\ or\ t}$ indicates whether the birth-municipality, m, was exposed to any pre-1965 severe typhoons either one year before or during the birth-year, t; and similarly for the other treatment variables. We use two-year windows here to avoid collinearity and to reduce the number of coefficients we have to estimate. By construction, α_0 and β_0 capture the effects of in utero exposure to severe typhoons, since exposure that took place one year before or during the birth year is possibly in utero exposure. α_{-1} and β_{-1} measure the effects of severe typhoons that took place before conception. α_1, α_2, β_1 and β_2 reflect the effects of post-natal exposure to severe typhoons.

Figure 1 shows the results of estimating Equation 4. Each panel of Figure 1 shows the results of separate regressions where the outcome variables are the fraction of males for Panel A, $\ln(cohort\ size)$ for Panel B, $\ln(male\ cohort\ size)$ for Panel C, and $\ln(female\ cohort\ size)$ for Panel D. In each panel, we plot the coefficient estimates and 95% confidence intervals of the key coefficients of interest from Equation 4. Coefficients of the pre-1965 typhoons: α_{-1}, α_0, α_1, and α_2, are plotted on the left-hand side of each panel; coefficients of the post-1965 typhoons: β_{-1},β_0, β_1, and β_2, are plotted on the right-hand side of each panel. Estimates for these regressions are also presented in Appendix Table A.8.

The contrast between pre-1965 and post-1965 typhoon exposures is evident in Figure 1. The estimates for α_0 are negative and statistically significant for three outcome variables: the fraction of males, cohort size, and male cohort size. In contrast, the estimates for β_0

are almost zero and statistically insignificant for all four outcome variables. These findings are consistent with our previous results that severe, pre-1965 typhoons substantially reduced cohort size, especially male cohort size, whereas severe post-1965 typhoons did not.[27]

Interestingly, however, α_{-1} and β_{-1}, which measure the effects of severe typhoons that took place before conception (two to three years before birth), are significantly different from zero for some outcome variables. Our results suggest that pre-conception exposure to severe, pre-1965 typhoons reduces *male* cohort size by 4 percent and the fraction of males by 0.893 percentage points, but has no detectable effects on *female* cohort size. For severe post-1965 typhoons, our results suggest that pre-conception exposure reduces *male* cohort size by 2.3 percent and reduces *female* cohort size by 4 percent. The effects on the fraction of males are small and not statistically significant. One channel through which pre-conception typhoon exposure can affect cohort size (and long-term human outcomes) is reduced household consumption and nutrient intake.[28]

Next, we perform the same analysis on long-term human capital outcomes. We estimate the equivalent of Equation 4 for education and occupational outcomes at the individual level and include as a control variable a dummy for male. Figure 2 presents the results. (Estimates are presented in Appendix Table A.9.) Again, pre-1965 typhoons had little impact on long-term outcomes, whereas post-1965 typhoons had large negative effects on both educational attainment and occupational skill level. In utero exposure has the largest impact; post-natal early childhood exposure has smaller but substantial impacts as well.

[27]We note that the estimate for α_0 is - 0.742 when using ln(*male cohort size*) as the outcome variable. This estimate is much smaller than the corresponding coefficient estimate, -0.144, in Table 3 (column 2). The treatment variable in Table 3 measures the expected number of in utero typhoon exposures for each birth cohort and weighs each typhoon that took place one year before or during the birth-year by the probability that the typhoon took place in utero for a given birth cohort. The treatment variable here is an indicator of whether any typhoon passed by either one year before or during the year of birth – it does not exclude typhoons that took place pre-conception; nor does it place a lower weight on typhoons that took place close to the end of the birth-year. The estimated effects here are the combined effects of in utero, pre-conception, and post-natal exposures and, hence, smaller than the estimates in Table 3. We also used the 1970 Census and find qualitatively similar results on mortality among those exposed to severe typhoons pre- and post-1965. However, the 1970 census provides the province of birth, not the municipality of birth. The analysis was, thus, done at the province level and the estimates are not precisely measured. These results are available upon request.

[28]We concede that it is not clear why pre-conception exposure to pre-1965 typhoons disproportionally affects male cohort size, whereas pre-conception exposure to post-1965 typhoons disproportionally affects female cohort size. We first note that, traditionally, most ethnic groups in the Philippines do not practice son preference. Prior research suggest that reductions in the nutrient intake may explain these findings. Mathews et al. (2008) provide some evidence that higher levels of maternal nutrition prior to conception is associated with a higher likelihood of male birth. Our pre-1965 results suggest that mothers who were exposed to pre-1965 typhoons prior to conception may have reduced their pre-conception nutrient intake, which lowered sex ratio. Anttila-Hughes and Hsiang (2013) find reductions in household assets and consumption as well as an increase in female infant mortality rate *three years after* typhoon exposure. Our post-1965 results are largely consistent with their findings.

Alternative cutoff year Although Marcos came into office after December 1965, major changes in disaster relief policy began only in December 1968 after the Casiguran earthquake. For robustness, we use December 1968 as the alternative cut-off time for policy change (Appendix Tables A.10, A.11, and A.12). We find similar patterns and an even greater contrast between the two time periods. Effects on cohort sizes are larger for the pre-Marcos period and smaller for the period under Marcos. Effects for most long-term outcomes remain small and insignificant pre-Marcos, whereas long-term effects for the period under Marcos become even larger. Similar to our earlier results, when we use the adult co-resident sample, the estimated effects are slightly larger with household fixed effects and for low-SES households. These results suggest that the change in the availability of disaster relief funding after December 1968 is the main contributor to the muted mortality effects in the period under Marcos.

Alternative exposure variables We use the expected number of typhoons an individual is exposed to as our main treatment variable. We assume a linear relationship between the expected number of typhoons in each stage of life and the outcome variables of interest. If some municipalities are exposed to multiple typhoons within a year and if there is a non-linear relationship between the number of exposures and the effects of each exposure, then Equations 1, 2, and 3 would lead to biased estimates. The concern for multiple typhoons is minimal – as indicated in Table 1, all municipalities are exposed to at most one severe typhoon each year; in less than 1 percent of municipality-year pairs, the municipality was struck by multiple small typhoons within the same year (mostly category 1).

To further alleviate the non-linearity concerns, we expand the analysis in Equation 4 to include exposure dummies for small typhoons. We also replace the exposure dummies in Equation 4 with count variables indicating the number of typhoon exposures during each stage of life. These two sets of alternative treatment variables (exposure dummies and count variables) yield very similar results, confirming that non-linearity concerns are minimal. These results are available upon request.

Alternative distance to the eye of the storm One limitation of our study is that we do not observe the actual size of the typhoon. In our main analysis, we assume that only municipalities within 30 kilometers of the eye of the storm are affected by the typhoon. If a typhoon is particularly large in size, municipalities outside of the 30-km radius may be just as affected as those within the 30-km radius. If this is the case for some typhoons, we may under-estimate the adverse effects of typhoons.[29]

To test whether the effects of typhoons extend beyond the 30-km radius, we add a second layer of treatment variables to municipalities that are between 30 and 60 kilometers from the eye of the storm and estimate the effects of typhoon exposure on them. These results are presented in Section 6.7 of the Appendix. Pre-1965 typhoons have limited effects on municipalities farther away from the eye of the storm. However, post-1965 typhoons have some negative effects on the cohort size of municipalities 30 to 60 kilometers from the storm path. One plausible explanation is that the average size of post-1965 severe typhoons is larger than pre-1965 severe typhoons. Additionally, disaster relief funding may have been more available for municipalities closer to the typhoon path.

Alternative storm intensity measures Our main analysis allows for only two storm intensity levels (small and severe). In Appendix Section 6.8, we allow for four levels: SS scale 1, 2, 3, and 4 or higher. We continue to combine SS scale 4 and 5 storms in one category because only a small number of municipalities are ever exposed to scale 5 storms. The results suggest that (1) in most cases, the impact of the storm increases with storm intensity, and (2) the magnitudes of the adverse effects are much larger for scale 4 and 5 storms than for scale 1, 2, or 3 storms. These results support our categorization of storm intensity.

Alternative explanations for the changing effects after 1965 Economic growth could have contributed to the changing effects of severe typhoons under the Marcos regime. However, the country's rapid growth began after1970,[30] whereas we observe a sharp change in the effects of severe typhoons between 1966 and 1972. To further explore the potential impact of economic development, we separate pre-1965 severe tyhoons by five-year windows to estimate the effects of severe typhoons over time (Appendix Tables A.17 and A.18). If economic development between 1966 and 1972 drives the changes in effects, we would expect the changes in the effects of typhoons to begin well before 1965. Instead, our results suggest that neither the mortality effects nor the long-term effects changed much between 1956 -1960 and 1961-1965. In contrast, there is a sharp change in the effects of severe typhoons after 1965. To the best of our knowledge, the post-disaster relief policy initiated by the Marcos regime

[29] Brand and Blelloch (1973) document that intense typhoons passing the Philippines between 1960 to 1970 have an average *eye diameter* of 20 to 30 miles, which translate to an *eye radius* of 16 to 24 kilometers. They also found that intense typhoons have smaller eye diameters but larger circulation sizes than less intense typhoons.

[30] Average annual per capita GDP growth rate in the Philippines was 1.9% between 1961 and 1965, 1.6% between 1966 and 1970, 3% in the 1970s, -0.9% in the 1980s, 0.5% in the 1990s and 3.4% between 2001 and 2016 (author's calculations with data from the World Bank's World Development Indicators).

is the only typhoon-related policy change between 1965 and 1972. Although we are unable to rule out other factors that may have contributed to the post-1965 changes in the effects of severe typhoons, all our results are consistent with the hypothesis that the post-disaster relief policy provided protective effects against typhoon-induced early-life mortality.

5 Conclusion

We find a strong dose-response effect to early-life exposure to natural disasters in a setting where natural disasters occur frequently – severe disasters are associated with adverse outcomes, whereas less intense events are associated with small or insignificant effects. These findings stand in stark contrast to findings from the U.S. and Brazil, where low-intensity tropical cyclones can have large negative effects on both short and long-term outcomes (Simeonova, 2011; Currie and Rossin-Slater, 2013; Karbownik and Wray, 2016; de Oliveira and Quintana-Domeque, 2016). One plausible explanation for the differences in the findings is the role of adaptation. Due to the high frequency of low-intensity typhoons in the Philippines, residents may be more prepared, both mentally and physically, to cope with lower intensity, somewhat expected natural disasters. Other evidence from the US also suggests that long-term adaptation mitigates the effects of short-term shocks (Zivin et al., 2018).

We find a strong negative relationship between mortality and long-term scarring effects. When the mortality effects of severe disasters are especially high (pre-1965 in our setting), we do not observe any differences in long-term outcomes between the survivors and those who were not exposed to the shock. This is consistent with findings in high selective mortality settings. After the introduction of disaster relief (post-1965 in our setting), the mortality effects of severe disasters are much more muted, and we observe large differences in the long-term outcomes for the survivors and the unaffected. The observed adverse outcomes due to scarring in a low mortality setting also reflect improved early-life survival. These contrasts suggest that research on early-life shocks in developing countries should pay special attention to selective mortality, since observed adverse long-term outcomes may be the result of the increased probability of survival (Currie and Vogl, 2013).

The provision of resources in the aftermath of a natural disaster has long been the focus in policy making in many countries and our findings underscore the importance of such assistance. Residents, particularly low-SES ones, are not prepared to cope with severe typhoons on their own. Therefore, policy makers should take into account both the community's familiarity with the disaster and the severity of natural disasters in implementing post-disaster interventions. Our results suggest that short-term assistance such as Marcos' disaster response policies in the late 1960s and 1970s have been especially effective in lowering the rate of early-life mortality caused by disasters. However, alleviating the long-term effects remains a challenge for future research and policy making. To this end, our finding that children from high-SES families in the post-1965 sample were somewhat shielded from the negative effects of severe typhoons offers a sense of hope – with strong infrastructure and sufficient post-disaster aid, complete resilience may be within reach even after the most ferocious disasters.

References

Adhvaryu, A., T. Molina, A. Nyshadham, and J. Tamayo (2015). Helping children catch up: Early life shocks and the Progresa experiment.

Aguilar, A. and M. Vicarelli (2011). El Nino and Mexican children: Medium-term effects of early-life weather shocks on cognitive and health outcomes. *Cambridge, United States: Harvard University, Department of Economics. Manuscript*.

Almond, D. (2006). Is the 1918 Influenza pandemic over? Long-term effects of in utero Influenza exposure in the post-1940 US population. *Journal of Political Economy 114*(4), 672–712.

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

Almond, D., J. Currie, and V. Duque (2017). Childhood circumstances and adult outcomes: Act II. Technical report, National Bureau of Economic Research.

Almond, D., L. Edlund, and M. Palme (2009). Chernobyl's subclinical legacy: Prenatal exposure to radioactive fallout and school outcomes in Sweden. *The Quarterly Journal of Economics 124*(4), 1729–1772.

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

Almond, D. and B. Mazumder (2013). Fetal origins and parental responses. *Annu. Rev. Econ. 5*(1), 37–56.

Anttila-Hughes, J. K. and S. M. Hsiang (2013). Destruction, disinvestment, and death: Economic and human losses following environmental disaster. *Available at SSRN 2220501*.

Arceo, E., R. Hanna, and P. Oliva (2016). Does the effect of pollution on infant mortality differ between developing and developed countries? Evidence from Mexico City. *The Economic Journal*.

Atkinson, J., A. Hicken, and N. Ravanilla (2014). Pork and typhoons: The influence of political connections on disaster response.

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

Bozzoli, C., A. Deaton, and C. Quintana-Domeque (2009). Adult height and childhood disease. *Demography 46*(4), 647–669.

Brand, S. and J. W. Blelloch (1973). Changes in the characteristics of typhoons crossing the Philippines. *Journal of Applied Meteorology 12*(1), 104–109.

Cunha, F. and J. Heckman (2007). The economics of human development: The technology of skill formation. *The American Economic Review 97*(2), 31–47.

Currie, J. and D. Almond (2011). Human capital development before age five. *Handbook of Labor Economics 4*, 1315–1486.

Currie, J. and M. Rossin-Slater (2013). Weathering the storm: Hurricanes and birth outcomes. *Journal of Health Economics 32*(3), 487–503.

Currie, J. and T. Vogl (2013). Early-life health and adult circumstance in developing countries. *Annu. Rev. Econ 5*, 1–36.

de Oliveira, V. H. and C. Quintana-Domeque (2016). Natural disasters and early human development: Hurricane Catarina and birth outcomes in Brazil.

Deaton, A. (2007). Height, health, and development. *Proceedings of the National Academy of Sciences 104*(33), 13232–13237.

Deuchert, E. and C. Felfe (2015). The tempest: Short-and long-term consequences of a natural disaster for children's development. *European Economic Review 80*, 280–294.

Doocy, S., A. Rofi, C. Moodie, E. Spring, S. Bradley, G. Burnham, and C. Robinson (2007). Tsunami mortality in Aceh province, Indonesia. *Bulletin of the World Health Organization 85*(4), 273–278.

Franklin, S. and J. Labonne (2017). Economic shocks and labour market flexibility. *Journal of Human Resources*, 0616–8012r1.

Gunnsteinsson, S., A. Adhvaryu, P. Christian, A. Labrique, J. Sugimoto, A. A. Shamim, and K. P. West Jr (2016). Resilience to early life shocks: Evidence from the interaction of a natural experiment and a randomized control trial.

Hanna, R. and P. Oliva (2016). Implications of Climate Change for Children in Developing Countries. *The Future of Children*, 115–132.

Hsiang, S. M. and A. S. Jina (2014). The causal effect of environmental catastrophe on long-run economic growth: Evidence from 6,700 cyclones.

Huigen, M. G. and I. C. Jens (2006). Socio-economic impact of super typhoon Harurot in San Mariano, Isabela, the Philippines. *World Development 34*(12), 2116–2136.

Jayachandran, S. (2009). Air quality and early-life mortality evidence from Indonesia's wildfires. *Journal of Human Resources 44*(4), 916–954.

Kannisto, V., K. Christensen, and J. W. Vaupel (1997). No increased mortality in later life for cohorts born during famine. *American Journal of Epidemiology 145*(11), 987–994.

Karbownik, K. and A. Wray (2016). Long-run consequences of exposure to natural disasters.

Knapp, K. R., J. A. Knaff, C. R. Sampson, G. M. Riggio, and A. D. Schnapp (2013). A pressure-based analysis of the historical western North Pacific tropical cyclone intensity record. *Monthly Weather Review 141*(8), 2611–2631.

Kraemer, S. (2000). The fragile male. *British Medical Journal 321*(7276), 1609.

Lam, H., M. H. Kok, and K. K. Y. Shum (2012). Benefits from typhoons–the Hong Kong perspective. *Weather 67*(1), 16–21.

Lin, M.-J. and E. M. Liu (2014). Does in utero exposure to illness matter? The 1918 influenza epidemic in Taiwan as a natural experiment. *Journal of Health Economics 37*, 152–163.

Liu, E., J.-T. Liu, and T.-Y. H. Tseng (2016). Fetal origins of mental health: Evidence from natural disasters in Taiwan.

Maccini, S. and D. Yang (2009). Under the weather: Health, schooling, and economic consequences of early-life rainfall. *American Economic Review 99*(3), 1006–1026.

Mathews, F., P. J. Johnson, and A. Neil (2008). You are what your mother eats: evidence for maternal preconception diet influencing foetal sex in humans. *Proceedings of the Royal Society of London B: Biological Sciences 275*(1643), 1661–1668.

Mathews, T., B. E. Hamilton, et al. (2005). Trend analysis of the sex ratio at birth in the United States. *National vital statistics reports 53*(20), 1–17.

Meng, X. and N. Qian (2009). The long term consequences of famine on survivors: Evidence from a unique natural experiment using China's great famine. Technical report, National Bureau of Economic Research.

Shah, M. and B. M. Steinberg (2017). Drought of opportunities: Contemporaneous and long-term impacts of rainfall shocks on human capital. *Journal of Political Economy 125*(2), 527–561.

Simeonova, E. (2011). Out of sight, out of mind? Natural disasters and pregnancy outcomes in the USA. *Cesifo Economic Studies 57*(3), 403–431(29).

Ugaz, J. and A. Zanolini (2011). Effects of extreme weather shocks during pregnancy and early life on later health outcomes: the case of Philippines' typhoons.

Warren, J. F. (2013). A tale of two decades: Typhoons and floods, Manila and the Provinces, and the Marcos years. *The Asia-Pacific Journal 11*, 43.

Yu, J., D. Tang, Y. Li, Z. Huang, and G. Chen (2013). Increase in fish abundance during two typhoons in the South China Sea. *Advances in Space Research 51*(9), 1734–1749.

Zivin, J. S. G., S. M. Hsiang, and M. J. Neidell (2018). Temperature and human capital in the short and long run. *Journal of the Association of Environmental and Resource Economists 5*(1), 77–105.

Tables and Figures

Table 1: Average Typhoon Exposures Across the Philippines, 1945-1972

Panel A: Average number of typhoons affecting **the Philippines** per year

Time Period	All Typhoons	Scale 1	Scale 2	Scale 3	Scale 4	Scale 5	Small	Severe
Period 1: 1945-1965	4.95	2.86	0.62	0.90	0.52	0.05	4.38	0.57
Period 2: 1966-1972	6.43	3.14	1.42	1.00	0.43	0.43	5.57	0.86
Overall: 1945-1972	5.32	2.93	0.82	0.93	0.50	0.14	4.68	0.64

Panel B: Average number of typhoons affecting **each municipality** per year, by island group

		Period 1: 1945-1965			Period 2: 1966-1972		
Island Group	Storm Intensity	Mean	Std. Dev.	Max	Mean	Std. Dev.	Max
Northern Luzon	Small	0.320	(0.561)	3	0.295	(0.556)	2
	Severe	0.010	(0.099)	1	0.019	(0.137)	1
Southern Luzon	Small	0.187	(0.430)	2	0.383	(0.641)	4
	Severe	0.001	(0.033)	1	0.049	(0.216)	1
Visayas	Small	0.155	(0.394)	3	0.259	(0.507)	3
	Severe	0.015	(0.123)	1	0.005	(0.072)	1
Mindanao	Small	0.030	(0.179)	2	0.078	(0.268)	1
	Severe	0.002	(0.044)	1	0	(0)	0
Overall	Small	0.172	(0.426)	3	0.248	(0.517)	4
	Severe	0.007	(0.085)	1	0.017	(0.130)	1

Note: Authors' calculations using JMA and TD-9635 data. Panel A shows the average number of typhoons that cross the Philippine archipelago every year. Panel B shows the average number of typhoons affecting each municipality per year. Geographic divisions and municipality boundaries are consistent with the 1990 Philippine Census. Number of municipalities = 1611. A municipality is affected if the centroid of the municipality lies within 30 km of the typhoon path. Typhoon intensity in Panel A refers to the highest intensity a typhoon ever reached over the Philippine archipelago. Storm intensity in Panel B refers to the intensity when the typhoon passed the corresponding municipality. A small typhoon is one whose highest intensity is SS scale 1, 2, or 3. A severe typhoon is one whose highest intensity is SS scale 4 or 5.

Table 2: Effects on Cohort Size

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Sample: Ages Cohorts 2 to 43				**Sample: Ages Cohorts 18 to 43**			
	ln(Cohort Size)	ln(Male Cohort)	ln(Female Cohort)	Fraction Male	ln(Cohort Size)	ln(Male Cohort)	ln(Female Cohort)	Fraction Male
Small typhoon in utero	-0.00841	-0.00612	-0.0138**	0.00162	-0.0110	-0.00749	-0.0174*	0.00181
	(0.00532)	(0.00639)	(0.00676)	(0.00169)	(0.00706)	(0.00888)	(0.00939)	(0.00252)
Small typhoon year 1&2	0.00102	-0.00274	0.00431	-0.00175**	-0.000798	-0.00209	5.23e-07	-0.000491
	(0.00265)	(0.00318)	(0.00308)	(0.000721)	(0.00326)	(0.00427)	(0.00390)	(0.00107)
Severe typhoon in utero	-0.0502**	-0.0769**	-0.0267	-0.0128*	-0.0735**	-0.111**	-0.0437	-0.0175
	(0.0253)	(0.0329)	(0.0296)	(0.00760)	(0.0304)	(0.0450)	(0.0363)	(0.0109)
Severe typhoon year 1&2	0.00919	0.00121	0.0156	-0.00297	0.00751	0.00375	0.00781	-0.000192
	(0.0115)	(0.0146)	(0.0129)	(0.00337)	(0.0128)	(0.0191)	(0.0147)	(0.00504)
Observations	62,286	62,286	62,286	62,286	38,558	38,558	38,558	38,558
R-squared	0.943	0.910	0.906	0.033	0.939	0.896	0.895	0.045
Mean of Cohort Size	724.68	365.78	358.91	0.5078	576.69	287.98	288.71	0.5056

Notes: Source for the outcome variables is the 10% housing sample of the CPH 1990. Cohort size is the estimated size of each cohort, estimated by summing up the weights of all individuals with non-missing information about the municipality of birth. Each column is a separate regression. Regressions are run at the birth-municipality by age-cohort level. For columns (1) to (4), the sample includes all cohorts aged 2 to 43 in 1990. For columns (5) to (8), the sample includes all cohorts aged 18 to 43 in 1990. For all columns, municipalities are restricted to those that have at least one male and one female in each age cohort for all ages under 43.

Small typhoon in utero is the expected number of small typhoons that passed within 30 km of the cohort's municipality of birth when the cohort was in utero. Similarly, small typhoon in 1st and 2nd years are the expected number of small typhoon during the first and second years after birth. Small typhoons are those with minimum central pressure between 945 and 999 mb, which correspond to a category 1, 2, or 3 typhoon on the Saffir-Simpson scale. Severe typhoons are those with central pressure at or below 944 mb, which correspond to category 4 and 5 typhoons on the Saffir-Simpson scale.

All regressions include municipality fixed effects, birth-year by island group fixed effects, and region-specific time trends. Standard errors are clustered two-way at both the municipality and the province-by-birth-year levels.

Table 3: Effects on Cohort Size - Before and After 1965

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Sample: Ages Cohorts 2 to 43				**Sample: Ages Cohorts 18 to 43**			
	ln(Cohort Size)	ln(Male Cohort)	ln(Female Cohort)	Fraction Male	ln(Cohort Size)	ln(Male Cohort)	ln(Female Cohort)	Fraction Male
Small typhoon in utero	-0.00746	-0.00862	-0.00962	-0.000328	-0.0113	-0.0120	-0.0133	-0.000291
pre-1965	(0.00959)	(0.0119)	(0.0119)	(0.00303)	(0.00864)	(0.0113)	(0.0108)	(0.00302)
Small typhoon year 1&2	0.00883*	0.00640	0.0101*	-0.000885	0.00643	0.00440	0.00773	-0.000812
pre-1965	(0.00502)	(0.00609)	(0.00569)	(0.00129)	(0.00432)	(0.00563)	(0.00499)	(0.00133)
Severe typhoon in utero	-0.0954***	-0.144***	-0.0602	-0.0224	-0.0871**	-0.133**	-0.0517	-0.0217
pre-1965	(0.0354)	(0.0552)	(0.0456)	(0.0144)	(0.0354)	(0.0560)	(0.0470)	(0.0147)
Severe typhoon year 1&2	0.00874	0.00423	0.00722	0.000590	0.00771	0.00816	0.00385	0.00238
pre-1965	(0.0186)	(0.0282)	(0.0181)	(0.00642)	(0.0168)	(0.0269)	(0.0168)	(0.00673)
Small typhoon in utero	-0.00944	-0.00499	-0.0169**	0.00287	-0.0126	4.32e-05	-0.0281	0.00627
post-1965	(0.00624)	(0.00735)	(0.00803)	(0.00198)	(0.0122)	(0.0149)	(0.0172)	(0.00444)
Small typhoon year 1&2	-0.00361	-0.00807**	0.000881	-0.00224***	-0.0147***	-0.0142**	-0.0151**	0.000283
post-1965	(0.00312)	(0.00356)	(0.00370)	(0.000820)	(0.00499)	(0.00635)	(0.00619)	(0.00169)
Severe typhoon in utero	-0.0183	-0.0287	-0.00410	-0.00556	-0.0444	-0.0584	-0.0309	-0.00598
post-1965	(0.0359)	(0.0405)	(0.0380)	(0.00766)	(0.0528)	(0.0700)	(0.0545)	(0.0152)
Severe typhoon year 1&2	0.00740	-0.00350	0.0192	-0.00550	-0.00161	-0.0126	0.00582	-0.00470
post-1965	(0.0146)	(0.0150)	(0.0182)	(0.00369)	(0.0185)	(0.0207)	(0.0273)	(0.00693)
Observations	62,286	62,286	62,286	62,286	38,558	38,558	38,558	38,558
R-squared	0.943	0.910	0.906	0.033	0.939	0.896	0.895	0.045
Mean of Y, pre-1965	507.53	254.53	253.01	0.5057	507.53	254.53	253.01	0.5057
Mean of Y, post-1965	904.07	457.68	446.39	0.5096	764.40	378.79	385.62	0.5054

Notes: The typhoon exposure variables are interacted with a dummy variable indicating whether the typhoon occurred before or after December 1965. All regressions include municipality fixed effects, birth-year by island group fixed effects, and region-specific time trends. Standard errors are clustered two-way at both the municipality and the province-by-birth-year levels. The mean of each outcome variable is presented in the last two rows. "Mean of Y, pre-1965" refers to the averages for cohorts aged 25 to 43. "Mean of Y, post-1965" refers to the averages for cohorts aged 2 to 24 for columns (1) to (4) and cohorts aged 18 to 24 for columns (5) to (8).

Table 4: Effects on Educational Attainment

	(1) Literacy	(2) Years of Education	(3) Completed High Sch.
Small typhoon in utero	0.00129	0.0287*	0.000422
pre-1965	(0.000846)	(0.0173)	(0.00232)
Small typhoon year 1&2	-7.12e-05	0.00735	-0.000707
pre-1965	(0.000437)	(0.00911)	(0.00124)
Severe typhoon in utero	0.00466	-0.0300	-0.0143
pre-1965	(0.00407)	(0.0666)	(0.00874)
Severe typhoon year 1&2	0.00145	-0.0595	-0.0143***
pre-1965	(0.00209)	(0.0384)	(0.00529)
Small typhoon in utero	-0.00145	-0.0119	-0.000968
post-1965	(0.00116)	(0.0228)	(0.00286)
Small typhoon year 1&2	-0.000635	-0.00669	-0.00159
post-1965	(0.000603)	(0.0135)	(0.00155)
Severe typhoon in utero	-0.00771*	-0.342***	-0.0181
post-1965	(0.00394)	(0.109)	(0.0139)
Severe typhoon year 1&2	-0.000442	-0.0614	-0.00966
post-1965	(0.00184)	(0.0465)	(0.00651)
Observations	2,290,886	2,255,017	2,255,017
R-squared	0.143	0.188	0.135
Mean of Y, pre-1965 cohorts	0.950	9.19	0.444
Mean of Y, post-1965 cohorts	0.961	9.70	0.519

Notes: Sample includes all individuals between the ages of 18 and 43 with non-missing information about the municipality of birth in the 10% housing sample of CPH1990. "Literacy" is a dummy variable indicating whether the respondent was literate as of May, 1990. "Years of education" refers to the respondent's completed years of education as of May, 1990. "Completed High School" is a dummy variable indicating whether the correspondent had completed high school as of May, 1990. Each column is a separate regression. Regressions are run at the individual level, whereas the treatment variables are defined at the birth-municipality by age-cohort level. Definitions of treatment variables are the same as in Table 4. All regressions include municipality fixed effects, birth-year by island group fixed effects, region-specific time trends, and a dummy for being male. Standard errors are clustered two-way at both the municipality level and the province-by-birth-year level.

Table 5: Effects on Occupational Skill Level

	(1) Skilled Occupation	(2) Associate Professional	(3) Professional	(4) Skilled Occupation	(5) Associate Professional	(6) Professional
Small typhoon in utero	0.00933***	0.00321**	0.00274**	0.00831***	0.00272*	0.00222*
pre-1965	(0.00299)	(0.00154)	(0.00131)	(0.00280)	(0.00139)	(0.00120)
Small typhoon year 1&2	0.00637***	0.00332***	0.00259***	0.00608***	0.00316***	0.00245***
pre-1965	(0.00172)	(0.00107)	(0.000921)	(0.00158)	(0.000998)	(0.000867)
Severe typhoon in utero	-0.00302	0.00949**	0.00794*	-0.00397	0.00871*	0.00700
pre-1965	(0.0105)	(0.00470)	(0.00462)	(0.0105)	(0.00454)	(0.00458)
Severe typhoon year 1&2	0.00108	0.00103	-0.000674	0.00290	0.00232	0.000607
pre-1965	(0.00550)	(0.00215)	(0.00215)	(0.00555)	(0.00206)	(0.00172)
Small typhoon in utero	0.00930	0.00217	0.00206	0.00976	0.00230	0.00224
post-1965	(0.00742)	(0.00274)	(0.00212)	(0.00711)	(0.00247)	(0.00189)
Small typhoon year 1&2	0.00438	0.00150	0.00154	0.00470	0.00180	0.00182
post-1965	(0.00330)	(0.00173)	(0.00147)	(0.00307)	(0.00157)	(0.00134)
Severe typhoon in utero	-0.159***	-0.0690***	-0.0519***	-0.145***	-0.0601***	-0.0448***
post-1965	(0.0421)	(0.0176)	(0.0131)	(0.0397)	(0.0157)	(0.0115)
Severe typhoon year 1&2	-0.0508***	-0.0252***	-0.0206***	-0.0500***	-0.0244***	-0.0198***
post-1965	(0.0113)	(0.00501)	(0.00392)	(0.0111)	(0.00492)	(0.00389)
Years of education	No	No	No	0.0381***	0.0252***	0.0215***
				(0.000665)	(0.000711)	(0.000615)
Observations	2,093,804	2,093,804	2,093,804	2,069,113	2,069,113	2,069,113
R-squared	0.146	0.045	0.037	0.232	0.146	0.125
Mean of Y, pre-1965 cohorts	0.313	0.101	0.084	0.313	0.101	0.084
Mean of Y, post-1965 cohorts	0.172	0.035	0.027	0.172	0.035	0.027

Notes: Outcome variables are dummy variables indicating whether the individual holds a skilled occupation (columns 1 and 4), an associate professional occupation (columns 2 and 5), or a professional occupation (columns 3 and 6). Each column is a separate regression. Regressions are run at the individual level, whereas the treatment variables are defined at the birth-municipality by age-cohort level. All regressions include municipality fixed effects, birth-year by island group fixed effects, region-specific time trends, and a dummy for being male. Standard errors are clustered two-way at both the municipality level and the province-by-birth-year level.

Table 6: Effects on Educational Attainment by Sex

	(1)	(2)	(3)	(4)	(5)	(6)
	Literacy		Years of Education		Completed High Sch.	
	Male	Female	Male	Female	Male	Female
Small typhoon in utero	0.00102	0.00154	0.00733	0.0516**	-0.000860	0.00193
pre-1965	(0.00107)	(0.00114)	(0.0229)	(0.0219)	(0.00314)	(0.00293)
Small typhoon year 1&2	2.48e-05	-0.000173	0.00691	0.00779	-0.000786	-0.000575
pre-1965	(0.000546)	(0.000557)	(0.0107)	(0.0116)	(0.00145)	(0.00161)
Severe typhoon in utero	0.00440	0.00480	-0.00734	-0.0540	-0.0215*	-0.00675
pre-1965	(0.00530)	(0.00555)	(0.102)	(0.0856)	(0.0125)	(0.0109)
Severe typhoon year 1&2	0.00191	0.000707	-0.0409	-0.0790	-0.0178**	-0.0107*
pre-1965	(0.00256)	(0.00318)	(0.0562)	(0.0485)	(0.00764)	(0.00568)
Small typhoon in utero	-0.000860	-0.00209	-0.0272	0.00467	-0.00263	0.00146
post-1965	(0.00141)	(0.00145)	(0.0262)	(0.0301)	(0.00395)	(0.00356)
Small typhoon year 1&2	-0.000608	-0.000738	0.00163	-0.0150	-0.000157	-0.00293
post-1965	(0.000690)	(0.000771)	(0.0132)	(0.0169)	(0.00182)	(0.00200)
Severe typhoon in utero	-0.00878*	-0.00685	-0.400***	-0.286**	-0.0259	-0.0128
post-1965	(0.00460)	(0.00520)	(0.113)	(0.131)	(0.0175)	(0.0164)
Severe typhoon year 1&2	0.000358	-0.00133	-0.0706	-0.0574	-0.00857	-0.0117
post-1965	(0.00180)	(0.00233)	(0.0435)	(0.0618)	(0.00697)	(0.00810)
Observations	1,144,609	1,146,277	1,127,900	1,127,117	1,127,900	1,127,117
R-squared	0.117	0.177	0.186	0.194	0.137	0.139
Mean of Y, pre-1965 cohorts	0.952	0.949	9.12	9.26	0.447	0.440
Mean of Y, post-1965 cohorts	0.959	0.963	9.41	9.83	0.485	0.552

Notes: Each column is a separate regression using the sub-sample of either male or female respondents in the CPH 1990 10% sample. All regressions include municipality fixed effects, birth-year by island group fixed effects, and region-specific time trends. Standard errors are clustered two-way at both the municipality level and the province-by-birth-year level.

Table 7: Effects on Occupational Skill Level by Sex

	(1)	(2)	(3)	(4)	(5)	(6)
	Skilled Occupation		Associate Professional		Professional	
	Male	Female	Male	Female	Male	Female
Small typhoon in utero,	0.0108***	0.00869***	0.00327	0.00326*	0.00247	0.00309*
pre-1965	(0.00414)	(0.00319)	(0.00221)	(0.00177)	(0.00185)	(0.00166)
Small typhoon year 1&2,	0.00494**	0.00791***	0.00308**	0.00361***	0.00269**	0.00253**
pre-1965	(0.00229)	(0.00173)	(0.00136)	(0.00115)	(0.00112)	(0.00106)
Severe typhoon in utero,	0.00612	-0.00999	-0.00362	0.0223***	-0.00908	0.0242***
pre-1965	(0.0146)	(0.0139)	(0.00826)	(0.00606)	(0.00684)	(0.00597)
Severe typhoon year 1&2,	-0.00227	0.00434	0.00315	-0.000887	0.00256	-0.00370
pre-1965	(0.00834)	(0.00431)	(0.00419)	(0.00318)	(0.00322)	(0.00326)
Small typhoon in utero,	0.0143	0.00552	0.00118	0.00301	0.00135	0.00254
post-1965	(0.0102)	(0.00609)	(0.00329)	(0.00269)	(0.00246)	(0.00219)
Small typhoon year 1&2,	0.00587	0.00287	0.00187	0.00100	0.00200	0.000974
post-1965	(0.00437)	(0.00325)	(0.00202)	(0.00164)	(0.00171)	(0.00139)
Severe typhoon in utero,	-0.183***	-0.144***	-0.0684***	-0.0703***	-0.0460***	-0.0579***
post-1965	(0.0553)	(0.0372)	(0.0194)	(0.0170)	(0.0138)	(0.0133)
Severe typhoon year 1&2,	-0.0702***	-0.0360***	-0.0307***	-0.0205***	-0.0242***	-0.0174***
post-1965	(0.0153)	(0.00991)	(0.00663)	(0.00451)	(0.00500)	(0.00389)
Observations	1,043,359	1,050,445	1,043,359	1,050,445	1,043,359	1,050,445
R-squared	0.201	0.066	0.062	0.035	0.048	0.030
Mean of Y, pre-1965 cohorts	0.415	0.221	0.101	0.102	0.078	0.090
Mean of Y, post-1965 cohorts	0.194	0.152	0.029	0.041	0.020	0.034

Notes: Each column is a separate regression using the sub-sample of either male or female respondents in the CPH 1990 10% sample. All regressions include municipality fixed effects, birth-year by island group fixed effects, and region-specific time trends. Standard errors are clustered two-way at both the municipality level and the province-by-birth-year level.

Table 8: Effects on Educational Attainment - Sibling Comparison

	(1)	(2)	(3)	(4)	(5)	(6)
	With Household Fixed Effects			**With Municipality Fixed Effects**		
	Literacy	Years of Education	Completed High Sch.	Literacy	Years of Education	Completed High Sch.
Small typhoon in utero,	0.00109	0.0428	-0.00617	0.00181	0.0718**	-0.00318
pre-1965	(0.00182)	(0.0353)	(0.00496)	(0.00144)	(0.0332)	(0.00455)
Small typhoon year 1&2,	-0.000502	0.00539	0.000447	-0.000870	-0.0264	-0.00785***
pre-1965	(0.000968)	(0.0196)	(0.00289)	(0.000806)	(0.0176)	(0.00255)
Severe typhoon in utero,	-0.00371	-0.0775	-0.00331	-0.00137	-0.361***	-0.0444**
pre-1965	(0.00862)	(0.132)	(0.0221)	(0.00721)	(0.126)	(0.0187)
Severe typhoon year 1&2,	-0.00109	-0.0950	-0.00617	0.00113	-0.0308	-0.00616
pre-1965	(0.00410)	(0.0807)	(0.0109)	(0.00364)	(0.0727)	(0.00825)
Small typhoon in utero,	0.000591	-0.000541	0.00160	-0.000840	-0.0192	0.000472
post-1965	(0.00138)	(0.0290)	(0.00412)	(0.00114)	(0.0252)	(0.00374)
Small typhoon year 1&2,	-0.000156	0.00386	-0.00236	-0.000520	0.0102	-0.000899
post-1965	(0.000640)	(0.0140)	(0.00200)	(0.000572)	(0.0124)	(0.00191)
Severe typhoon in utero,	-0.00749	-0.472***	-0.0149	-0.00419	-0.222**	0.0166
post-1965	(0.00483)	(0.122)	(0.0154)	(0.00397)	(0.0953)	(0.0168)
Severe typhoon year 1&2,	-6.18e-05	-0.0842**	-0.00722	3.40e-05	-0.00529	0.000257
post-1965	(0.00211)	(0.0382)	(0.00659)	(0.00163)	(0.0414)	(0.00613)
Observations	586,234	575,982	575,982	586,233	577,819	577,819
R-squared	0.665	0.776	0.702	0.101	0.172	0.127
Mean of Y, pre-1965	0.968	10.69	0.629	0.968	10.69	0.629
Mean of Y, post-1965	0.973	10.36	0.605	0.973	10.36	0.605

Notes: Sample restricted to those in the 10% housing sample of CPH 1990 who still live in the same household as their parents and whose reported relationship to the household head is that of either "son" or "daughter." Regressions in columns (1) to (3) include household fixed effects, birth-year by island group fixed effects, region-specific time trends, and a dummy for being male. Regressions in columns (4) to (6) include municipality fixed effects, birth-year by island group fixed effects, region-specific time trends, and a dummy for being male.

Table 9: Effects on Occupational Skill Level - Sibling Comparison

	(1)	(2)	(3)	(4)	(5)	(6)
	With Household Fixed Effects			**With Municipality Fixed Effects**		
	Skilled Occupation	Associate Professional	Professional	Skilled Occupation	Associate Professional	Professional
Small typhoon in utero,	0.0190**	0.0137***	0.00804*	0.0279***	0.0146***	0.0108***
pre-1965	(0.00769)	(0.00473)	(0.00467)	(0.00655)	(0.00380)	(0.00344)
Small typhoon year 1&2,	0.00607	0.00110	0.000965	0.0138***	0.00601**	0.00461*
pre-1965	(0.00410)	(0.00300)	(0.00297)	(0.00372)	(0.00283)	(0.00252)
Severe typhoon in utero,	-0.00556	-0.00665	-0.00986	0.00222	0.00478	0.00506
pre-1965	(0.0324)	(0.0165)	(0.0136)	(0.0311)	(0.0106)	(0.00942)
Severe typhoon year 1&2,	-0.0343**	-0.00542	-0.0102	0.000247	0.00950	0.00181
pre-1965	(0.0157)	(0.00909)	(0.00707)	(0.0155)	(0.00948)	(0.00769)
Small typhoon in utero,	0.0112*	0.00106	0.000498	0.0108*	0.00300	0.00243
post-1965	(0.00625)	(0.00275)	(0.00220)	(0.00635)	(0.00284)	(0.00236)
Small typhoon year 1&2,	0.00469	0.00238	0.00243*	0.00565*	0.00358*	0.00333*
post-1965	(0.00320)	(0.00190)	(0.00147)	(0.00289)	(0.00206)	(0.00180)
Severe typhoon in utero,	-0.126***	-0.0646***	-0.0483***	-0.124***	-0.0620***	-0.0493***
post-1965	(0.0379)	(0.0179)	(0.0129)	(0.0328)	(0.0140)	(0.0110)
Severe typhoon year 1&2,	-0.0460***	-0.0272***	-0.0212***	-0.0461***	-0.0281***	-0.0221***
post-1965	(0.0123)	(0.00583)	(0.00497)	(0.0103)	(0.00465)	(0.00394)
Observations	483,553	483,553	483,553	502,380	502,380	502,380
R-squared	0.595	0.525	0.510	0.161	0.084	0.071
Mean of Y, pre-1965	0.407	0.143	0.117	0.407	0.143	0.117
Mean of Y, post-1965	0.187	0.042	0.032	0.187	0.042	0.032

Notes: Sample restricted to those in the 10% housing sample of CPH 1990 who still live in the same household as theirparents and whose reported relationship to the household head is that of either "son" or "daughter." Regressions in columns (1) to (3) include household fixed effects, birth-year by island group fixed effects, region-specific time trends, and a dummy for being male. Regressions in columns (4) to (6) include municipality fixed effects, birth-year by island group fixed effects, region-specific time trends, and a dummy for being male.

Table 10: Effects on Education - Sibling Comparison By Household Head Occupation

	(1)	(2)	(3)	(4)	(5)	(6)
	Sample: Household Head Unskilled Occ			**Sample: Household Head Skilled Occ**		
	Literacy	Years of Education	Completed High Sch.	Literacy	Years of Education	Completed High Sch.
Small typhoon in utero	0.00260	0.0351	-0.00714	-0.00223	0.0390	-0.00177
pre-1965	(0.00224)	(0.0434)	(0.00606)	(0.00245)	(0.0590)	(0.00771)
Small typhoon year 1&2	-0.000888	-0.00245	0.000769	0.000452	0.0146	0.000977
pre-1965	(0.00119)	(0.0224)	(0.00335)	(0.00150)	(0.0331)	(0.00480)
Severe typhoon in utero	-0.00692	-0.162	-0.0103	0.00769	0.145	0.0251
pre-1965	(0.0109)	(0.170)	(0.0280)	(0.00975)	(0.195)	(0.0323)
Severe typhoon year 1&2	-0.00219	-0.109	-0.00902	0.000766	-0.0982	0.00442
pre-1965	(0.00558)	(0.0974)	(0.0122)	(0.00616)	(0.120)	(0.0186)
Small typhoon in utero	0.000858	0.000787	0.00314	-0.000394	-0.0553	-3.64e-05
post-1965	(0.00176)	(0.0313)	(0.00480)	(0.00182)	(0.0452)	(0.00695)
Small typhoon year 1&2	8.97e-05	0.00831	-0.00335	-0.000680	-0.0176	0.000206
post-1965	(0.000855)	(0.0163)	(0.00247)	(0.000811)	(0.0212)	(0.00300)
Severe typhoon in utero	-0.00884	-0.399***	-0.0159	-0.00569	-0.284*	-0.0179
post-1965	(0.00657)	(0.139)	(0.0199)	(0.00507)	(0.156)	(0.0255)
Severe typhoon year 1&2	0.000210	-0.0707	-0.00324	-0.000701	-0.0701	-0.00618
post-1965	(0.00285)	(0.0504)	(0.00804)	(0.00258)	(0.0670)	(0.00889)
Observations	412,824	405,935	405,935	173,410	170,047	170,047
R-squared	0.679	0.769	0.695	0.510	0.735	0.662
Mean of Y, pre-1965	0.956	10.20	0.577	0.988	12.17	0.787
Mean of Y, post-1965	0.964	9.72	0.526	0.992	11.75	0.776

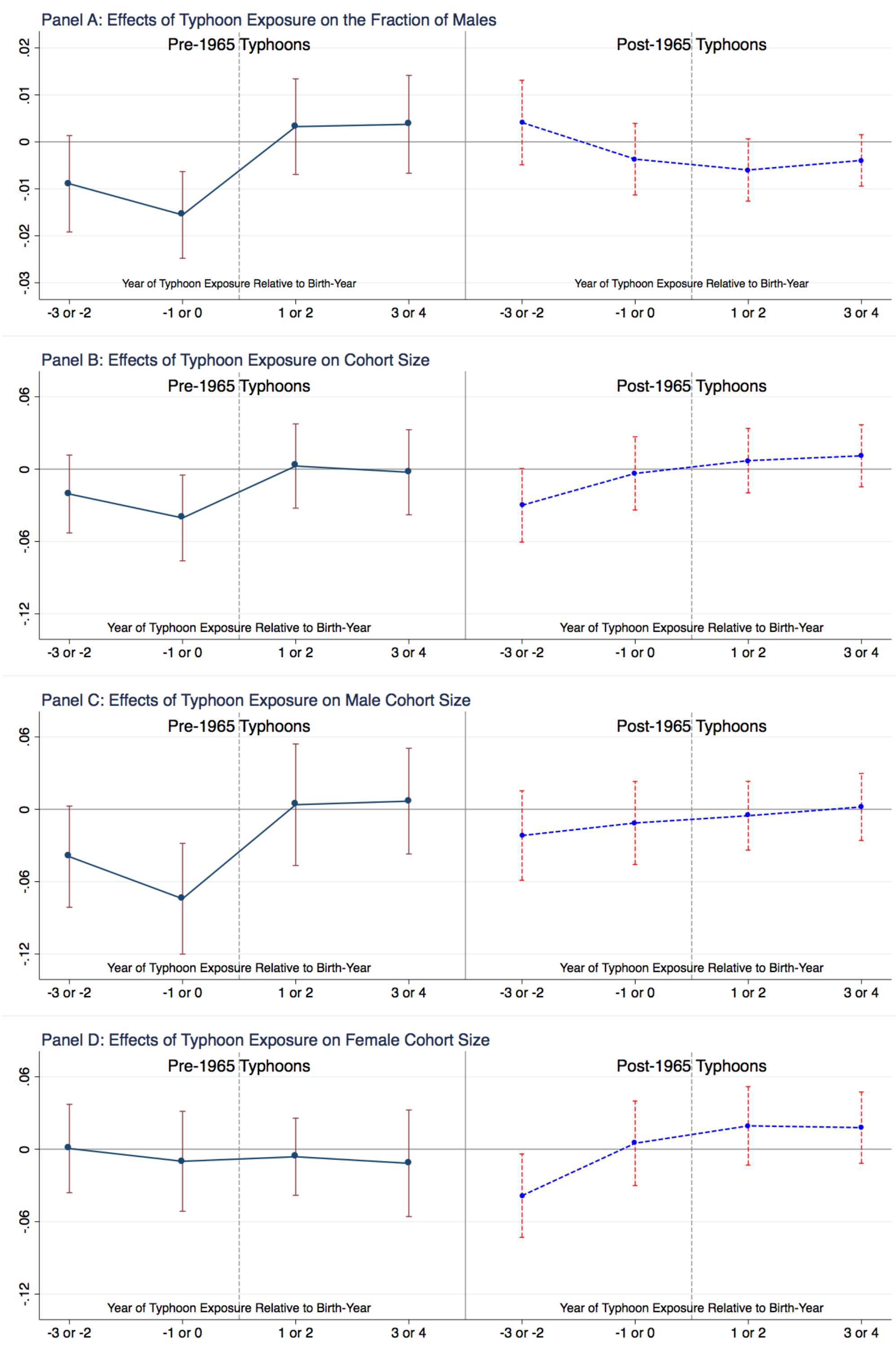
Notes: Sample restricted to those in the 10% housing sample of CPH 1990 who still live in the same household as their parents and whose reported relationship to the household head is that of either "son" or "daughter." For columns (1) to (3), the sample is further restricted to children of households where the household head has an unskilled occupation. For columns (4) to (6), the sample is further restricted to children of households where the household head has a skilled occupation. All regressions include household fixed effects, birth-year by island group fixed effects, region-specific time trends, and a dummy for being male.

Table 11: Effects on Occupation - Sibling Comparison By Household Head Occupation

	(1)	(2)	(3)	(4)	(5)	(6)
	Sample: Household Head Unskilled Occ			**Sample: Household Head Skilled Occ**		
	Skilled Occupation	Associate Professional	Professional	Skilled Occupation	Associate Professional	Professional
Small typhoon in utero,	0.0110	0.00478	0.00151	0.0190	0.0275**	0.0184*
pre-1965	(0.00856)	(0.00526)	(0.00484)	(0.0148)	(0.0119)	(0.0109)
Small typhoon year 1&2,	0.000901	-0.00341	-0.00262	0.00717	0.00735	0.00609
pre-1965	(0.00399)	(0.00284)	(0.00296)	(0.00855)	(0.00644)	(0.00613)
Severe typhoon in utero,	-0.0341	-0.0298	-0.0216	0.0623	0.0566	0.0195
pre-1965	(0.0277)	(0.0203)	(0.0177)	(0.0454)	(0.0394)	(0.0295)
Severe typhoon year 1&2,	-0.0300**	0.00232	0.00233	-0.0774***	-0.0466**	-0.0630***
pre-1965	(0.0147)	(0.00884)	(0.00824)	(0.0240)	(0.0194)	(0.0180)
Small typhoon in utero,	0.00705	-0.000598	-0.000151	0.00993	0.000870	-0.000827
post-1965	(0.00554)	(0.00256)	(0.00206)	(0.00909)	(0.00522)	(0.00436)
Small typhoon year 1&2,	0.00333	0.00220	0.00199	0.00235	0.000274	0.00154
post-1965	(0.00300)	(0.00156)	(0.00127)	(0.00486)	(0.00318)	(0.00269)
Severe typhoon in utero,	-0.107***	-0.0531***	-0.0391***	-0.0569	-0.0402*	-0.0316*
post-1965	(0.0362)	(0.0161)	(0.0119)	(0.0386)	(0.0226)	(0.0167)
Severe typhoon year 1&2,	-0.0340***	-0.0176***	-0.0149***	-0.0218	-0.0204**	-0.0118
post-1965	(0.0120)	(0.00531)	(0.00457)	(0.0168)	(0.00864)	(0.00731)
Observations	345,476	345,476	345,476	138,077	138,077	138,077
R-squared	0.587	0.512	0.496	0.599	0.539	0.526
Mean of Y, pre-1965	0.345	0.114	0.094	0.602	0.234	0.192
Mean of Y, post-1965	0.151	0.029	0.023	0.266	0.071	0.054

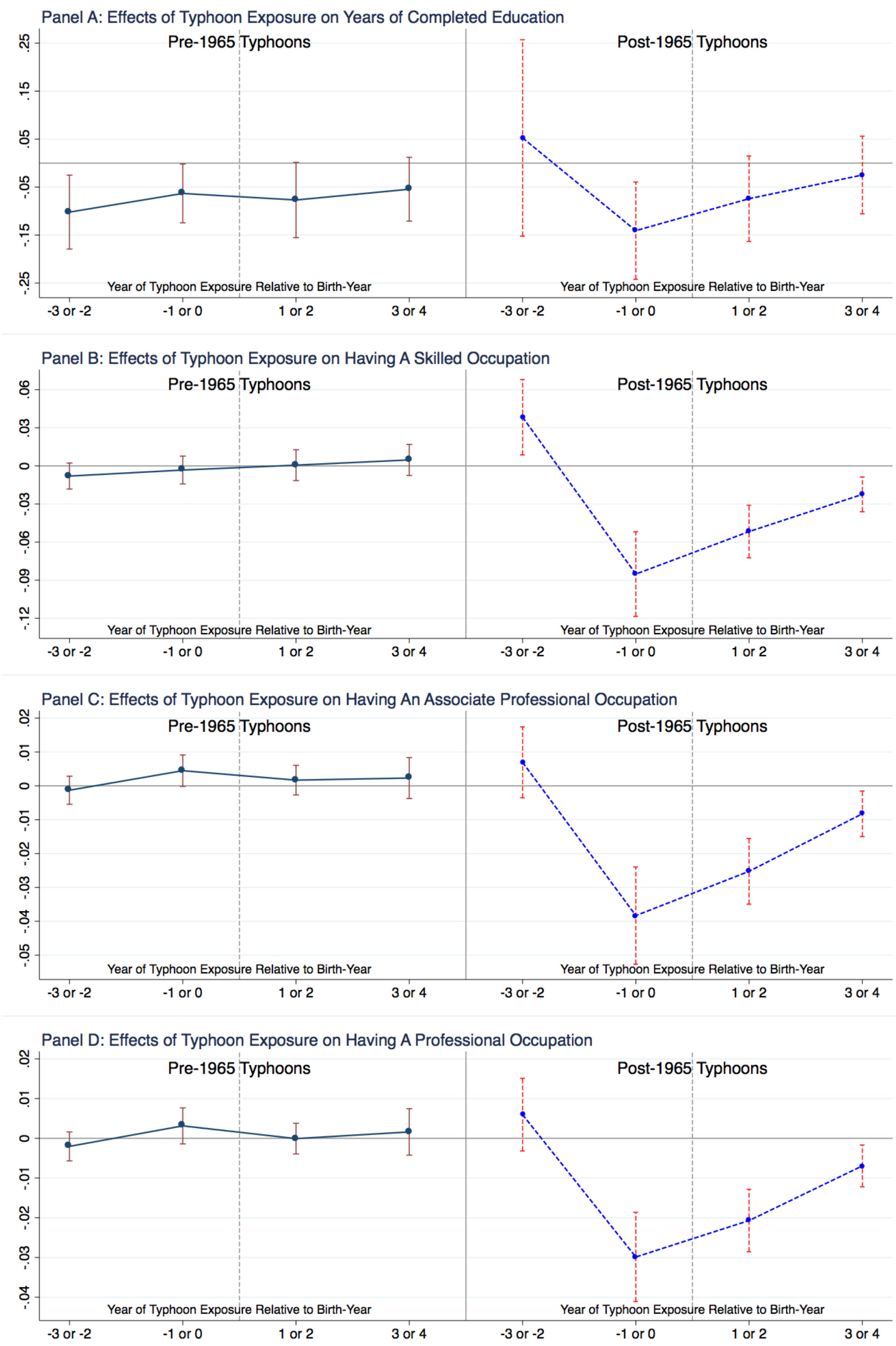
Notes: Sample restricted to those in the 10% housing sample of CPH 1990 who still live in the same household as their parents and whose reported relationship to the household head is that of either "son" or "daughter." For columns (1) to (3), the sample is further restricted to children of households where the household head has an unskilled occupation. For columns (4) to (6), the sample is further restricted to children of households where the household head has a skilled occupation. All regressions include household fixed effects, birth-year by island group fixed effects, region-specific time trends, and a dummy for being male.

Figure 1: Effects of Severe Typhoons on Cohort Size by Year of Exposure



Notes: Each panel shows the results of a separate regression where the outcome variable is regressed on eight dummy variables indicating whether a severe pre-1965 or post-1965 typhoon passed each municipality-birth-year 2 to 3 years before the birth-year / 0 to 1 year before the birth-year / 1 to 2 years after the birth-year / 3 to 4 years after the birth-year, as well as municipality fixed effects, age-by-island-group fixed effects, and region-specific time trends. The left side of each panel shows the coefficient estimates and 95% confidence intervals of the four dummy variables associated with pre-1965 typhoons, and the right side post-1965 typhoons. The regressions are run at the municipality-age-cohort level. The sample includes cohorts between the ages of 2 and 43 in 1990 and municipalities that have at least one male and one female in each age cohort for all ages under 43 in the 1990 Census 10% Housing Survey. Robust standard errors are clustered two-way at both the municipality level and the province-by-birth-year level.

Figure 2: Effects of Severe Typhoons on Education and Occupation by Year of Exposure



Notes: Each panel shows the results from a separate regression where the outcome variable is regressed on eight dummy variables indicating whether a severe pre-1965 or post-1965 typhoon passed each municipality-birth-year 2 to 3 years before the birth-year / 0 to 1 year before the birth-year / 1 to 2 years after the birth-year / 3 to 4 years after the birth-year, as well as municipality fixed effects, age-by-island-group fixed effects, and region-specific time trends. The left side of each panel shows the coefficient estimates and 95% confidence intervals of the four dummy variables associated with pre-1965 typhoons, and the right side post-1965 typhoons. The sample includes all individuals between the ages of 18 and 43 with non-missing information about the municipality of birth in the 10% housing sample of CPH1990. Robust standard errors are clustered two-way at both the municipality level and the province-by-birth-year level.