Fetal Origins of Implicit Theories of Intelligence:
Evidence from Tropical Cyclones in the Philippines

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Para kay Lyka at sa lipunang pinangarap niya…

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

BMI	body mass index
GIS	geographic information system
IBTrACS	International Best Track Archive for Climate Stewardship
ITI	Implicit Theory of Intelligence
ISCED	International Standard Classification of Education
JMA	Japanese Meteorological Agency
JTWC	United States’ Joint Typhoon Warning Center
NAMRIA	National Mapping and Resource Information Authority
NEDA	National Economic and Development Authority
NOAA	National Oceanic and Atmospheric Administration
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
OLS	ordinary least squares
PAG-ASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PSA	Philippine Statistics Authority
PSU	primary sampling unit
RMW	radius of maximum winds
RSMC	Regional Specialized Meteorological Centre
STEP	Skills Toward Employment and Productivity
TC	tropical cyclone

Abstract

The relevance of non-cognitive skill to schooling, labor force participation, and other adult outcomes has become a crucial point of interest in contemporary economic research. It has been found that students who believe that intelligence can be developed are more likely to succeed academically and respond better to adversity and social exclusion. However, how these beliefs or mindsets are determined outside the classroom are scarcely explored. Exploiting a natural experiment arising from the prevalence of tropical cyclones in the Philippines, this study examines the effects of experiencing natural disasters to long-term mindset formation. Results reveal that exposure to more tropical cyclones during in utero and infancy leads adults, particularly rural women, to believe that intelligence is fixed and cannot be developed with the effect potentially mediated by poor childhood nutrition and health. Such findings point to the significance of prioritizing infant and maternal care in disaster and climate policy.

Keywords: implicit theories of intelligence, fetal origins hypothesis; tropical cyclones; climate change

I. Introduction

The economic literature has long declared the association of cognition and educational attainment with economic and social outcomes such as wages, health, criminal activity, and violence (Angrist & Krueger, 1990; Card, 1999; Cutler & Lleras-Muney, 2006; Lochner & Moretti, 2004; Rapp et al., 2012). These emphasize the importance of improving academic performance and increasing schooling years to eliminate poverty and inequality. Today, contemporary research has shifted some focus toward the relevance of non-cognitive skill and personality traits to schooling, labor force participation, and other measures of lifetime success (Brunello & Schlotter, 2011; Carneiro et al., 2007; García, 2016; Kautz et al., 2014).

In the realm of social and development psychology, recent developments show that individuals who believe that one's intelligence or ability is malleable and can be developed are more likely to perform well in school and respond better to social exclusion and adversity (Aronson et al., 2002; Claro et al., 2016; Dweck & Leggett, 1988; Dweck & Master, 2008; Romero et al., 2014; Yeager & Dweck, 2012). Since these findings, the formation of such incremental implicit theories of intelligence (ITIs), more commonly known as *growth mindsets*, has become a matter of great interest. This has resulted to experiments and interventions which seek to cultivate and *teach* growth mindsets in hopes that these could be scaled up to induce the above-mentioned academic, economic, and social outcomes (Blackwell et al., 2007; Yeager et al., 2019).

However, two crucial issues remain. First, the determinants of ITI outside the classroom setting have scarcely been explored. Previous studies show that individuals from low-income households (Claro et al., 2016) and backgrounds disadvantaged due to racial bias (Aronson et al., 2002) are more likely to hold entity ITIs or *fixed mindsets*, the belief that intelligence is crystallized and unchangeable. Conversely, the above psychological studies all find that students who hold such fixed mindsets are more likely to respond negatively to failure and challenges. In spite of this, other household or community conditions which either bring forth fixed mindsets or prevent the formation of growth mindsets have not been comprehensively identified. This gap in the literature is critical as such conditions, if not addressed, may diminish or even counteract the effectiveness of growth mindset interventions for those who are most in need of them (Dweck & Yeager, 2019). Second, the focus on the school setting also prevents the measurement of and inquiry into adult mindsets. If certain experiences cause children to hold fixed mindsets, it may be possible that their effects persist into adulthood. Thus, should fixed mindsets in adults be determined by early life conditions, then corresponding policies and interventions are much more vital than previously thought.

To fill these gaps, some clues may be found in the likewise emerging literature on the fetal origins hypothesis. Barker (1990) argues that individuals who had been exposed to adverse conditions in utero are more prone to suffering chronic illnesses later into adulthood. Economic studies have since expanded on this by exploring a wide array of circumstances in different periods of early life e.g., pandemics, economic depressions, and civil conflicts to analyze their impact on various adult outcomes such as educational attainment, asset holding, and even non-cognitive skill (Akresh et al., 2012; Almond & Mazumder, 2014; Banerjee et al., 2007; Bundervoet et al., 2009; Cutler et al., 2010; Giuliano & Spilimbergo, 2014; Maccini & Yang, 2009; Majid, 2015; Malmendier & Nagel, 2011; Mu & Zhang, 2011; Neelsen & Stratmann, 2011; Shoji, 2021; Singhal, 2019; Venkataramani, 2012).

This study bridges the gaps in the literature by estimating the impact of early life tropical cyclone (TC) exposure on adult ITI. The exogenous frequency, intensity, and trajectory of tropical cyclones are known to adversely affect households located near the Pacific, Indian, and Atlantic Oceans. Because these may cause damage to property, shifts to household consumption, and the reallocation of investments away from health and education (Anttila-Hughes & Hsiang, 2013; Deuchert & Felfe, 2015; Herrera-Almanza & Cas, 2021; Hsiang & Narita, 2012; Mendelsohn, 2000; Sawada, 2017; Sotomayor, 2013; Viganò & Castellani, 2020), there is reason to believe that experiencing tropical cyclones during childhood has a long-lasting effect on mindset formation.

The present study employs data from the Skills Toward Employment and Productivity (STEP) Skills Measurement Household Survey and a unique tropical cyclone frequency index constructed using data from the International Best Track Archive for Climate Stewardship (IBTrACS) and the "Philippines – Subnational Administrative Boundaries" geographic dataset from the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) in the Philippines. The STEP is a uniquely designed household survey which has been used to measure non-cognitive or socio-emotional skills in low and middle-income countries. Meanwhile, the index tracks the respondents' early life tropical cyclone experience by matching them with their respective provinces' exposure to tropical cyclones during several periods of their childhood. It is believed that the repeated exposure of countries such as the Philippines to tropical cyclone shocks may have long-term dampening effects on financial, human, and social capital accumulation at the household level and these have not been explored due to a previous lack of data (Anttila-Hughes & Hsiang, 2013). The identification strategy exploits the natural experiment arising from the exogenous variation in the trajectory and frequency of tropical cyclones that enter the Philippine Area of Responsibility. Such a design may be subject to potential threats including sample selection and measurement error of the respondents' birthplace, age, and tropical cyclone exposure. These will be discussed in due course.

Following an ordinary least squares (OLS) model, this study finds that increased exposure to tropical cyclones during in utero and infancy leads adults to believe that their intelligence is fixed and cannot be developed. Furthermore, rural women are more prone to holding fixed mindsets due to intrauterine and infant tropical cyclone exposure compared to rural men. Such findings are also robust for non-migrants and respondents below the age of 50. Moreover, the impact of intrauterine and infant tropical cyclone exposure is significant when individuals had lived closer to the path of tropical cyclones' eyewalls where rainfall and wind speeds are at their strongest. Finally, suggestive evidence shows that these effects may be mediated by poor childhood nutrition and health.

These findings contribute to the economic literature on tropical cyclones and natural disasters through the following: First, previous studies primarily highlight the short-to-medium term impact of tropical cyclones on macroeconomic indicators and household consumption and investment behavior (Anttila-Hughes & Hsiang, 2013; Callaghan et al., 2007; Yang & Choi, 2007). This paper supplements these findings by investigating how such household and macro-level shocks may persist and affect individuals in the long-term. Of particular interest are their effects on adult non-cognitive skill which are becoming increasingly relevant to understanding and promoting human development. Second, existing studies on the effects of tropical cyclones measure exposure using indicators such as amount of rainfall, maximum windspeed, and economic damage. However, the *repeated exposure* to natural disasters may have serial and compounded adverse effects and these have yet to be explored. This study attempts to fill this gap by measuring the frequency of tropical cyclone shocks and observing their impact years later. Lastly, this paper contributes to the literature regarding the formation of beliefs on the "returns to effort". Earlier studies associate prior exposure to adverse conditions with beliefs about financial market participation, political inclination, core self-evaluation, and locus of control (Giuliano & Spilimbergo, 2014; Krutikova & Lilleør, 2015; Malmendier & Nagel, 2011; Shoji, 2021). This study points to the connection between early life circumstances and individuals' beliefs about their abilities and the value of skills development.

This study also makes two contributions to the psychological literature on mindset theory. First, previous studies primarily focus on the importance of academic intervention and scantly explore other determinants of mindset formation. As of this paper's writing, it is the first to explore the potential fetal origins of ITI by exploiting the exogenous variation of climatic shocks. Whereas existing studies show how socioeconomic status, parental motivation, and racial stereotype threats may lead to fixed mindsets, this research adds to these by introducing two other sources: early life weather circumstances and childhood health. Second, majority of existing studies on ITI are based in developed countries in the Americas or Europe and often target school-aged individuals. This paper adds breadth by studying mindset in adults using data collected from a developing country.

Parallels can be drawn between this paper and the earlier work of Brzeziński (2017), Deuchert and Felfe (2015), Herrera-Almanza and Cas (2021), Maccini & Yang (2009), and Shoji (2021). Both Shoji (2021) and Maccini and Yang (2009) look at the effects of early life weather shocks – in their case, the experience of lower and higher rainfall – on adult outcomes such as non-cognitive skill, namely locus of control, and asset accumulation. However, this study observes a different kind of weather shock, tropical cyclones, and its effects on another kind of non-cognitive skill, ITI. Although periods of rainfall or temperature deviations are just as potentially devastating, tropical cyclones are frequently occurring climatic *events* with destructive effects on housing, livelihood, and infrastructure. Because these are intensifying due to anthropogenic climate change (Knutson et al., 2015; J. Kossin et al., 2020; Yumul et al., 2011), their effects may exacerbate even further, demanding a separate and diverse portfolio of research and policy interventions. Meanwhile, Brzeziński (2017) also makes use of the STEP survey to study the association between childhood circumstances e.g., childhood socio-economic status and parental background and adult outcomes such as educational attainment, wages, and life satisfaction. It also uses personality traits, particularly the Big Five and grit, as controls. Contrarily, this study attempts to link adult personality with early life circumstances that are not recorded in the STEP survey, acknowledging that the effects of childhood experiences on adult mindset may be mediated through other adult outcomes e.g., health and education, and vice versa. Finally, Deuchert and Felfe (2015) and Herrera-Almanza and Cas (2021) evaluate the long-term effects of Super Typhoon Mike in 1991 and Super Typhoons Herming and Sisang in 1987, respectively, on educational attainment. This paper supplements these findings by estimating the impact of *frequent* exposure in early life to tropical cyclones with varying degrees of strength on adult non-cognitive skill. It can then be argued that all these studies are complementary in the sense that they provide an abundance of evidence highlighting the association between early life circumstances and adult outcomes.

This study is outlined as follows: Section II proposes the linkages between early life tropical cyclone exposure and adult mindset based on the existing threads in the psychological, economic, and meteorological literatures. Section III and Section IV describe the data utilized and the ensuing identification strategy, respectively. Section V presents the empirical results, while Section VI addresses potential threats to identification and conducts tests for robustness. Section VII discusses potential underlying mechanisms and finally, Section VIII concludes.

II. Conceptual Framework

A. Implicit Theories of Intelligence: Significance and Mechanics of Formation

The literature on implicit theories of intelligence, more commonly known as *mindsets*, finds its roots in the areas of animal learning and human attribution which saw compelling breakthroughs during psychology's cognitive revolution in the late 1960s' (Dweck & Yeager, 2019). Studies on learned helplessness show that dogs previously exposed to uncontrollable shocks made little to no effort to resist or prevent subsequent shocks, even when these were made controllable or avoidable (Seligman & Maier, 1967). Meanwhile, research on human attribution, the process by which people perceive and explain cause and effect, observe that students who attribute failure to a *lack of ability* are more likely to give up in the face of setbacks, whereas those who blame failure on the *lack of effort* are more willing to repeat tasks even after failure (Weiner & Kukla, 1970). Two conjectures can be derived from these findings. First, it is clear that past experiences inform individuals' estimation of their abilities. Second, because individuals' beliefs about themselves are directly linked to their perceived control over situations and outcomes, these may be pivotal in understanding motivation and predicting behavior.

Using these as basis, Ellen Leggett (1985) proposes that individuals' mindsets, defined as their beliefs on the nature of their own intelligence or ability, could be categorized as either incremental or entity; incremental or *growth* theorists believe that intelligence is a malleable and fluid quality that can be developed while entity or *fixed* theorists hold that intelligence is uncontrollable and crystallized. Leggett and Dweck (1988) later find that children with growth mindsets are more likely to be interested in improving their skills and competence, while those with fixed mindsets are more inclined to accomplish tasks in order to receive praise or avoid punishment. Later studies also show that compared to fixed theorists, those who hold growth mindsets are more likely to welcome challenges if they lead to higher levels of skill mastery (Blackwell et al., 2007), exert initiative toward self-regulated learning (Dweck & Master, 2008), and see failure as a setback which can be corrected with increased effort (Dweck et al., 1995).

It is through such mechanisms that psychologists believe mindsets could predict academic performance and other outcomes. Previous research shows that believing intelligence is malleable reliably leads to an upward trajectory in grades among school-aged individuals (Blackwell et al., 2007; Romero et al., 2014; Yeager et al., 2019). Growth mindsets among disadvantaged persons such as students from low-income families, those subjected to racial bias, and teenagers transitioning from middle school to high school are also associated with higher resilience, allowing them to overcome academic setbacks associated with adversity, social exclusion, and victimization (Aronson et al., 2002; Claro et al., 2016; Yeager & Dweck, 2012).

Given these strands in the literature, recent studies emphasize honing growth mindsets in children to achieve the predicted desirable outcomes. Blackwell and colleagues' (2007) academic intervention which directly *teaches* growth mindsets is one example. Through eight sessions, students are explicitly taught that learning changes the brain by forming new neural pathways, and that they have agency in and control of this process. This concept of "malleable intelligence" is presented through a required reading that makes use of vivid analogies and examples and is subsequently supported by group activities and discussions. They find that such an intervention promoted the motivation of a class of 7^{th} graders, further improving the grades of students who had already been performing well and reversing the trajectory of those who were previously at-risk of failure. More recently, a similar growth mindset intervention delivered online to a nationally representative sample of middle to high school students in the United States by (Yeager et al., 2019) was determined to have improved the grades among low-achieving students and increased participation in advanced mathematics courses.

This focus on motivation is consistent with the findings of Haimovitz and Dweck (2017) who observe that mindset is not inherited i.e., parents do not necessarily pass on their own ITIs to their children. Both stress a "sustained focus on the process of learning" (p. 1853): parents who view and communicate failure as opportunities for learning tend to foster growth mindsets in their children. On the other hand, very little has been understood about the other determinants of ITIs outside the classroom setting and why some students are predisposed towards having fixed mindsets. Case studies which center high school students from low-income backgrounds in Chile (Claro et al., 2016) and African-American college students (Aronson et al., 2002) show that both groups are more likely to hold fixed mindsets suggesting that the lack of access to educational resources and "stereotype threat" could play a hand in making people believe that their intelligence cannot be developed. Interestingly, in both studies along with a meta-analytic review by (Sisk et al., 2018), students from such disadvantaged backgrounds are the most likely to benefit from growth mindsets or growth mindset interventions as these could temper the effects of their handicap, whether perceived or material, on achievement.

What is important then for ITI formation is not the adult figure's respective ITI – whether it be the teachers' or the parents' – but how individuals are *taught* and *motivated* to respond to challenges and value education. Although directly teaching growth mindsets appears to have considerable benefits in the short-term, the identification of other factors which either bring forth fixed mindsets or prevent the formation of growth mindsets may just be as crucial if these could dampen or even counteract the effectiveness of interventions for those who are most in need of them.

B. The Fetal Origins Hypothesis and Early Life Weather Shocks

The likewise emerging literature on the fetal origins hypothesis may provide some leads to this quandary. In a 1990 paper, David Barker argues that individuals who had experienced adverse living conditions from in utero to childhood, such as poor maternal environment, housing, and diet, are more likely to become overweight as adults. Sufferers are also found to be more prone to diagnosis of diseases associated with obesity, including cardiovascular problems and diabetes. These suggest that the effects of poor "critical period" conditions are persistent and that they may remain latent until late into adulthood.

The impact of programming appears to extend far beyond physiological health. Because early life circumstances and shocks affect household consumption, investment, preferences, and beliefs, they also have implicit effects on the long-term accumulation of financial, human, and social capital. A review by Almond and Currie (2011) as well as their supplementary appraisal with Duque (2018) finds compelling evidence across multiple studies that the effects of programming during the critical periods from preconception to childhood extend to "bread and butter" economic outcomes such as educational attainment and wages and also to other developing economic research areas including personality and non-cognitive skill.

For example, it was found that adult Muslims who had been exposed to maternal fasting during Ramadan in utero are more likely to be disabled, primarily due to nutritional deprivation (Almond & Mazumder, 2014). Additionally, Majid (2015) uncovers that such individuals perform more child labor, score lower in cognitive and math tests, work fewer hours, and are more likely to be self-employed.

Conditions in the periods after pregnancy and infancy are also vital. In two separate studies involving individuals who had experienced times of recession, it was revealed that such groups reported less financial risk-taking behavior and stock market participation (Malmendier & Nagel, 2011), increased preference toward government redistribution and left-wing politics, and belief that success depends more on luck than effort (Giuliano & Spilimbergo, 2014). While the latter paper comprises only those who had experienced economic downturn during early adulthood, the former involves a wider cross-sectional sample of households, some of which were headed by individuals who had experienced the Great Depression as infants or children. Such results illustrate how exposure to negative conditions in different periods of life affect adult behavior through beliefs formed from an interplay of both primacy and recency effects.

Due to the vast implications of Barker's hypothesis, focus has been directed to the effects of a wide array of early life circumstances e.g., civil conflicts (Akresh et al., 2012; Bundervoet et al., 2009; Singhal, 2019) or outbreaks of diseases and famines (Banerjee et al., 2007; Cutler et al., 2010; Mu & Zhang, 2011; Neelsen & Stratmann, 2011; Venkataramani, 2012). Another such emerging space in the literature is on the consequences of weather conditions during childhood.

Perhaps one of the most seminal is the study conducted by Maccini and Yang (2009) on the effects of higher rainfall. Using cross-sectional data, the two find that Indonesian women who had experienced higher rainfall during infancy were taller, completed more schooling years, and resided in households that score higher on an asset index. The most plausible explanation for such results is that higher rainfall increases agricultural output which in turn leads to higher household incomes that are allocated toward healthcare and education.

Following Maccini and Yang, a study by Krutikova and Lilleør (2015) reveals that increased rainfall during in utero leads to higher adult core self-evaluation, a latent personality trait that indicates "the degree to which one has a generally positive and proactive view of oneself and one's relationship with the world" (p. 3). Much recently, using longitudinal data from 46 developing countries, Shoji (2021) finds ample complementary evidence that experiencing rainfall *shortages* during early childhood leads people to believe that they cannot control life outcomes and that such beliefs are plausibly mediated by the impact of lower rainfall on parenting quality. Both studies point to the role early life weather conditions play in personality and belief formation which could potentially be extended to mindsets.

C. The Climatology and Impact of Tropical Cyclones in the Philippines

Because many developing countries are dependent on favorable weather for livelihood and productivity, it must then follow that geographical regions which are most prone to weather shocks and meteorological or hydrological disasters are also most susceptible to their potential long-term negative impact.

In 2005, the World Bank's Hazard Management Unit identified the Philippines as one of the countries that is most prone to natural disaster hazards due to both its geography and geology (Dilley et al., 2005). Situated along the Pacific Ring of Fire, the Southeast Asian nation is vulnerable to earthquakes and eruptions from its 24 active volcanoes (Delos Reyes et al., 2018). However, tropical cyclones, which are often accompanied by flooding, landslides, and storm surges, are the most frequently occurring hazards.

According to Cinco et al. (2016), an average of 19.4 tropical cyclones enter the Philippine Area of Responsibility each year, around nine of which cross the country and make landfall. The island of Luzon in the Northern Philippines is the region most hit by tropical cyclones which are more prevalent during the latter half of the year between the months of July and November (Lyon & Camargo, 2009). Although the group does not observe significant trends in the annual number of tropical cyclones that enter the Philippine Area of Responsibility, they find that more extreme tropical cyclones (above 150 km/h) have affected the country of late. This is consistent with the findings based on Philippine tropical cyclone data from the previous decade and large-scale studies of meteorological activity across the globe which report that tropical cyclones have been intensifying in recent years due to anthropogenic climate change and global warming (Knutson et al., 2015; J. Kossin et al., 2020; Yumul et al., 2011).

Empirically, Anttila-Hughes and Hsiang (2013) estimate that an average Filipino household's income is reduced by 6.57% due to tropical cyclone exposure in the previous year. Significant reductions to human capital investments are also found, such as those toward education (13.3%) and medicine (14.3%). Subsequent studies by Deuchert and Felfe (2015) and Herrera-Almanza and Cas (2021) later find that individuals who had experienced in childhood one or two super typhoons – tropical cyclones with maximum wind speeds exceeding 220 km/h – are more likely to have lower educational attainment, suggesting the perverseness of tropical cyclones' effects on capital accumulation. Given the frequency with which tropical cyclones impact the Philippines, households must already consider and include risks associated with disasters in their decisions (Hsiang & Narita, 2012; Mendelsohn, 2000; Sawada, 2017; Viganò & Castellani, 2020); thus, the continued observance of large negative effects to households suggests that adaptation mechanisms are lacking, expensive, or both. At the same time, the unanticipated increased frequency of tropical cyclones, e.g., a province experiencing two more tropical cyclones in a year when based on previous experience only three are expected annually, may also subvert household expectation and budget allocation potentially leading to even more debilitating effects, whether direct or possibly long-term.

D. Pathways to Mindset Formation

Given these arguments, early life tropical cyclone frequency shocks might affect mindset formation through two underlying mechanisms namely, education and health.

First, the psychological literature deems the classroom as the most crucial channel for mindset formation. Case studies show that the exclusion from educational resources due to poverty (Claro et al., 2016) and racial bias (Aronson et al., 2002) leads individuals to hold fixed mindsets. As tropical cyclones and other natural disasters may damage infrastructure such as schools and roads as well as private property and livelihood, they have been likewise found to reduce school enrolment and attendance (Anttila-Hughes & Hsiang, 2013; Cuaresma, 2010).

Similarly, disasters may also force parents to allocate more time and resources toward labor, asset recovery, or migration (Deuchert & Felfe, 2015; Herrera-Almanza & Cas, 2021; Kochar, 1999; Morduch, 1995; Morten, 2019; Nguyen et al., 2015; Takasaki et al., 2004 as cited by Shoji, 2021). These may prevent them from paying attention to their children, particularly in their education (Haushofer & Fehr, 2014 as cited by Shoji, 2021). Although parents' mindsets are not necessarily passed on, their lack of involvement in their children's studies may reduce the latter's motivation and the value they attribute to studying and developing their skills (Haimovitz & Dweck, 2017). This is crucial as parental involvement is strongly associated with educational attainment (Gonzalez-DeHass et al., 2005; Pomerantz & Grolnick, 2017; Topor et al., 2010).

Thus, if tropical cyclones lower educational attainment because of school closures and shifts in academic calendars, absences or non-enrolment due to finances being diverted away from tuition and allowances, and reduced parental involvement, these may lead to fixed mindsets as well.

Second, although these have not yet been explored in the literature on mindset theory, it is plausible that critical period development and childhood health could be determinants of mindsets. To illustrate, Callaghan et al. (2007) find that Hurricane Katrina, a Category 5 (254 km/h) Atlantic tropical cyclone which ravaged the U.S. Gulf Coast in 2005, caused disruptions in the supply of clean water for drinking and bathing, inadequate access to safe food, interruption of health care and clinical care infrastructure, and other adverse conditions which directly affected up to 56,000 pregnant women and 75,000 infants. Anttila-Hughes and Hsiang

(2013) further observe that investments toward medicine and healthcare are reduced by 14.3% a year after cyclone exposure which may prove crucial to the long-term health development of fetii in utero and infants. True enough, Sotomayor (2013) reveals that individuals who had been exposed to the 1928 San Felipe and 1932 San Ciprián hurricanes during in utero and infancy were more likely to report a diagnosis of hypertension, high cholesterol, and diabetes, consistent with Barker's hypothesis.

Prior research has shown that children with poor health tend to receive fewer investments (Lynch & Brooks, 2013) including breastfeeding which is linked to the attainment of critical development milestones for infants and younger children (Sacker et al., 2006). Furthermore, children with disabilities and development delays e.g., those who weigh less, are of shorter stature, or have less motor and cognitive skills than their peers, associate their perceptions of their health with their ability to play and participate in school (Almqvist et al., 2006; Benjamin et al., 2017). Therefore, should tropical cyclones create conditions that are detrimental to critical period programming, whether during in utero or infancy, their effects on childhood health may spillover to mindsets causing individuals to believe that their ability or intelligence is deficient and cannot be developed.

III. Data

The present study makes use of two datasets. The first is the STEP Skills Measurement Household Survey, a uniquely designed household survey which includes modules that measure non-cognitive or socio-emotional skills in low and middle-income countries. The STEP household survey has been conducted from 2012 to 2017 in four waves, the third of which was carried out in Kosovo, Serbia, and the Philippines between 2015 and 2016.

A four-stage sample design was implemented in the Philippine survey (World Bank, 2018). Urban barangays[1] are defined in the survey as barangays with a population over 5,000, those with at least one establishment over 100 employees, or those with five or more establishments of 10 to 99 employees and with five or more defined public facilities within 2 km of the barangay administrative center. The primary sampling unit (PSU) is the urban barangay segment which divides urban barangays into approximately equally sized segments, each containing around 100 households.

First, 200 PSUs and 25 replacement PSUs are randomly selected from the 5,028 urban barangays identified. Second, 15 dwellings and 15 replacement dwellings e.g., neighborhood compounds, apartment complexes, or condominiums are chosen in each PSU using a systematic random method. Third, one household is selected from each dwelling with equal probability. Finally, one non-institutionalized individual aged 15 to 64 is randomly selected from each household. Non-institutionalized individuals are defined as those who do not reside in institutions e.g., prisons and hospitals, senior homes and hospices, and other group dwellings such as college dormitories and halfway homes.

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[1] The Philippines is divided into four primary geographic and administrative segments. The first are the 17 regions which span the three main island groups of Luzon, Visayas, and Mindanao in the Northern, Central, and Southern Philippines, respectively. These 17 regions are further subdivided into 81 provinces which then comprise 146 cities and 1,488 municipalities. These are finally partitioned into the 42,046 barangays, the country's smallest administrative unit.

An overall response rate of 94.8% was achieved in the Philippines with a total of 3,000 individuals interviewed, of which 165 are replacements[2].

A crucial limitation of this survey is that it does not have information on the birthplace of respondents. Incorrectly assuming that all respondents were born in their current province of residence may result to a bias if they include migrants from a province which had been exposed to more frequent tropical cyclones during their childhood. This study addresses this by exploiting that the respondents who have had some degree of formal education were asked whether the province of their most recent educational institution attended was the same as that of their current residence. Those who previously studied outside their provinces were confirmed to be migrants and are therefore excluded from the sample.

The remaining 2,498 respondents are then assumed to be more likely to have resided in the same province since birth. However, included in this sample are 576 respondents who did not have any formal schooling and thus cannot be verified to having been born in their province of residence at the time of the survey. Furthermore, migration before schooling cannot be fully ruled out even for the respondents who have studied in the same province, suggesting the potential for bias.

Nevertheless, such a bias, if any, is unlikely to be severe in the dataset. First, Bohra-Mishra and colleagues (2017) argue that although higher typhoon incidence results in more internal outmigration these are often short-distanced, with families using social networks to move to the nearest safe location (Dun, 2011; Gray & Mueller, 2012; Hassani-Mahmooei & Parris, 2012; Lu et al., 2012; Martin et al., 2014), and are driven by reduced agricultural output. Second, they also find that men and those with higher levels of education are more likely to migrate farther due to climate variability as financial, social, and human capital are strong determinants of migration (Bohra & Massey, 2009; Massey & Espinosa, 1997). These arguments support the use of the location of the last school attended as a proxy for birthplace as none of the respondents are in the agricultural sector and, if they did migrate, they are more

[2] 25 replacement PSUs and 15 replacement dwellings/households within each of the 225 PSUs are selected as reserves. The latter are activated when pre-selected households cannot respond due to refusal or inability to be interviewed, language problems, interviewers' difficulty in identifying dwellings, etc. In the case of the 2015-2016 Philippine cohort, the 25 replacement PSUs were not utilized, and 165 dwellings were activated due to the non-response of 165 pre-selected households.

likely to move within their province. At the same time, those with no education and whose birthplace cannot be "verified" by the proxy are unlikely to be migrants given their lack of capacity to migrate. Third, if the sampling did result to bias, it would merely be an attenuation bias. Therefore, estimation results are not expected to change qualitatively as long as statistically significant impacts of tropical cyclones are found. Finally, robustness checks will be conducted later using the sample comprising only those who studied in the same province.

Table 1 presents the descriptive statistics of the sample derived from the STEP household survey. The average respondent is observed to be around 37 years old, born in 1977 with 8.349 years of completed schooling. Figure A1 maps the geographic distribution of the survey respondents available for analysis. It is important to note that although the survey covers all 17 administrative regions, it is not nationally representative as it only has respondents from 39 out of 81 provinces including the four districts of the National Capital Region and only focuses on urban barangays as it has defined.

A distinct feature of the STEP survey is that includes a module about the respondents' life satisfactions, time and risk preference, and implicit theories of intelligence. However, the survey only makes use of single-item questions to elicit life satisfaction, time preference, and risk aversion which may have validity and reliability issues (Schmidt, 2018). On the other hand, the survey employs five questions to draw the respondents' ITI, three of which are derived from Dweck et al.'s (1995) "Growth Mindset Scale", particularly:

Now we would like to ask you some different questions. For these questions, we want to know how much you agree or disagree with them[. From a scale of 1 or "strongly disagree" to 6 or "strongly agree",] How much do you agree or disagree with this statement…

1. *You have a certain amount of intelligence, and you really can't do much to change it.*
2. *Your intelligence is something about you that you can't change very much.*
3. *You can learn new things, but you cannot really change your basic intelligence.*

The scale has been used in previous research to reliably elicit the ITI of African American college students (Aronson et al., 2002), financially disadvantaged high school students (Claro et al., 2016), and adults (Thompson et al., 2013). In the STEP sample, Cronbach's alpha is observed to be 0.92 demonstrating the high internal consistency and validity of the items. Responses are then averaged to obtain the ITI scores. Mean ITI score in the sample is 2.893 with a standard deviation of 1.417. Figure 1 illustrates the histogram of results from the survey. The two humps in the distribution highlight the bimodal divide of ITIs between growth and fixed mindsets.

Table 1. Summary Statistics

Statistic	N	Mean	St. Dev.	Min	Max
TC Exposure from in Utero to Infancy	2,498	0.019	0.799	-3.061	4.727
TC Exposure from 1 to 6	2,498	-0.015	1.243	-4.182	8.182
TC Exposure from 7 to 12	2,498	0.098	1.258	-6.182	9.818
Implicit Theory of Intelligence	2,498	2.893	1.417	1	6
Male	2,498	0.514	0.500	0	1
Age	2,498	37.130	12.839	15	64
Year of Birth	2,498	1,977.222	12.825	1,950	2,000
Non-migrant	1,922	1.000	0.000	1.000	1.000
Mother's Education	2,498	1.333	1.703	0	4
Father's Education	2,498	1.603	1.739	0	4
Years of Education Completed	2,498	8.349	5.418	0	19
Completed High School or Equivalent	2,498	0.632	0.482	0	1
Height	2,498	158.298	11.940	122	183
Weight	2,498	61.780	14.236	25	119
Chronic Disease	2,498	0.151	0.358	0	1
Underweight	2,498	0.099	0.299	0	1
Obese	2,498	0.169	0.375	0	1
Days Inactive Due to Illness (last four weeks)	2,498	0.705	1.969	0	14
Employed Full-Time	2,498	0.338	0.473	0	1
Self-employed	2,498	0.222	0.416	0	1
Unemployed	2,498	0.066	0.249	0	1
Bank Account Ownership	2,498	0.327	0.469	0	1
Low Socio-economic Status	2,498	0.215	0.411	0	1
Mid Socio-economic Status	2,498	0.610	0.488	0	1
High Socio-economic Status	2,498	0.175	0.380	0	1
Health Insurance Ownership	2,498	0.616	0.486	0	1

Various measures for adult outcomes are also readily available in the survey. In terms of health, height was measured in centimeters while weight was self-reported in kilograms. Variables for body mass index (BMI) classifications such as "underweight" (BMI < 18.5) and "obese" (BMI > 30) are derived from these measures. Respondents were also asked if they were suffering from chronic diseases such as diabetes, asthma, cancer, hypertension, etc., and also the number of days they were not able to conduct their usual activities due to such chronic diseases, other health problems, and/or accidents.

Also included in the survey are the respondents' parents' educational attainment. These are recorded based on the International Standard Classification of Education (ISCED) where "0" indicates no formal schooling or pre-school completion, "1" denotes completion of elementary education, "2" implies junior high school completion, "3" refers to senior high school completion, and "4" indicates tertiary education completion or higher.

For this study, respondents with low, medium, and high socio-economic status are categorized as those belonging in the first, second to fourth, and fifth asset wealth index quintiles, respectively. Bank account ownership and access to health insurance were also recorded as indicative measures of household wealth and socio-economic status (Psaki et al., 2014).

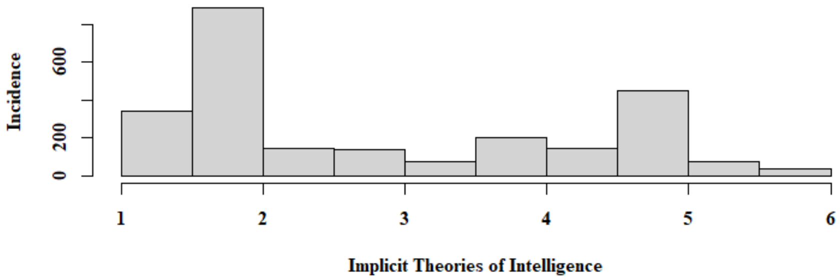

Figure 1. Histogram of Implicit Theory of Intelligence Scores

The second dataset utilized in the present study is a unique tropical cyclone frequency index constructed using the Western Pacific tropical cyclone best track dataset (BTD) from the National Oceanic and Atmospheric Administration's (NOAA) International Best Track Archive for Climate Stewardship (IBTrACS) and the "Philippines – Subnational Administrative Boundaries" geographic dataset from the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) in the Philippines.

IBTrACS contains aggregated BTDs from various operational meteorology agencies such as the United States' Joint Typhoon Warning Center (JTWC) and the Japanese Meteorological Agency's (JMA) Regional Specialized Meteorological Centre (RSMC) in Tokyo (Knapp et al., 2010). These BTDs comprise data such as the location of tropical cyclones, wind speeds and radii which are recorded in three-hour intervals. The JMA-RSMC is responsible for recording tropical cyclone activity and issuing relevant advisories within the Western Pacific basin where the Philippine archipelago is located.

From the dataset spanning from 1884 to the present, the tracks of 984 tropical cyclones which entered the Philippine Area of Responsibility from 1949 to 2014 were identified.

Tropical depressions, or tropical cyclones with a maximum wind speed of 61 km/h, recognized by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAG-ASA) were excluded because they are not recorded by the JMA-RSMC.

Meanwhile, the OCHA's dataset comprises the geographic boundaries of three of the four administrative levels of the Philippines, namely, the regional, provincial, and municipal and city levels. It is derived from survey data from the Philippine Statistics Authority (PSA) and the National Mapping and Resource Information Authority (NAMRIA) (OCHA, 2020).

To construct the index, the tropical cyclone tracks and provincial administrative boundaries are first rendered using geographic information system (GIS) software. Then, a spatial join algorithm is used to tally how many times a provincial boundary is directly traversed by tropical cyclones each year beginning in 1949. A summary of the climatology of tropical cyclones in the Philippines is depicted in Figure 2 highlighting the geographical variation of tropical cyclone exposure in the country, consistent with the observations of Cinco et al. (2016).

The weather shock is thus defined as the tropical cyclone exposure shock given by the formula $Weather_{jt} = W_{jt} - \overline{W_j}$ where W_{jt} denotes the number of tropical cyclone exposures in province j in year t and $\overline{W_j}$ is the provincial mean. After combining the two datasets according to the respondents' birth province and year, the shock is identified for three periods: from in utero to infancy (-1 to 0 years of age), early childhood (1 to 6), and late childhood (7 to 12). Childhood is divided into pre-school and elementary school periods corresponding with the country's education system prior to its full shift to K-12 in 2016. The histograms for each measure are depicted in Figure 3.

Around 8.69% of the STEP sample had been exposed to at least one more tropical cyclone during in utero and infancy compared to the mean exposure frequency of their respective provinces. The maximum exposure observed is from a 36-year-old female who had experienced during in utero and infancy 4.727 or roughly 5 tropical cyclones more than the two-year mean of her birth province, Quezon.

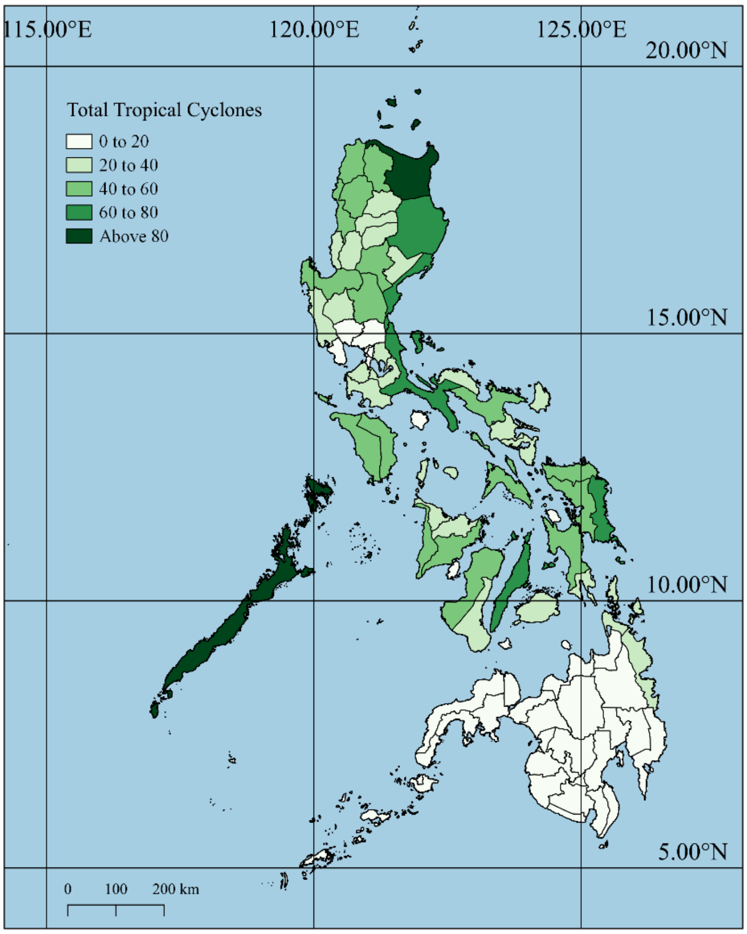

Figure 2. Philippine Tropical Cyclone Frequency Heatmap from 1949 to 2014.

IV. Identification Strategy

This study measures the effect of tropical cyclone exposure in early life on adult ITI following the ordinary least squares (OLS) model:

$$ITI_{ijt} = \beta Weather_{jt} + \mu X_i + \theta_j + \delta_t + \epsilon_{ijt} \quad (1)$$

where the dependent ITI_{ijt} is the mindset score of respondent i, born in province j in year t. The coefficient of interest is β, the impact of the vector of explanatory variables $Weather_{jt}$ which include the slate of previously defined tropical cyclone exposure shocks for each period of early life: during in utero and infancy, from ages one to six, and from ages seven to twelve. The vector X_i comprises controls for gender and the respondents' parents' educational attainment. Birth province and year fixed effects are also controlled by θ_j and δ_t, respectively. Tropical cyclone experience variability should be common among individuals born in the same area or year (Maccini & Yang, 2009). For example, provinces in Northern and Central Philippines are more likely to experience weather shocks compared to those in the South as illustrated by Figure 2. Such characteristics must be absorbed by provincial and annual fixed effects. Controls for other characteristics such as the respondents' educational attainment, employment, or socio-economic status, either in childhood or at the time of the survey, are not included as these could potentially be determined by early life circumstances and may dampen the magnitude of β. Finally, ϵ_{ijt} is the mean-zero error term. Because provinces are the level of treatment and these may exhibit unknown patterns of serial and spatial correlation, standard errors are clustered into the 39 birth provinces observed in the sample (Anttila-Hughes & Hsiang, 2013; Conley, 1999; Maccini & Yang, 2009).

The identification strategy exploits the natural experiment arising from the exogenous variation in timing and trajectory of such cyclone shocks. As highlighted by Figure 2, some provinces are more prone to experience tropical cyclones than others and these are most likely to form from July to November. However, unanticipated increased frequencies of tropical cyclones are also observed, and these may subvert household expectation and budget allocation.

The specification outlined above is subject to potential threats e.g., sample selection and measurement errors regarding variables such as the birthplace of the survey respondents, their reported age, and the construction of tropical cyclone weather shocks which may confound possible findings. Extreme weather events are highly associated with fetal and infant mortality as well as patterns of migration which may lead to selection into the sample (Deschênes & Moretti, 2009) At the same time, the inclusion of the 576 respondents who do not have any formal schooling and older respondents who might misreport their age may result to attenuation bias if they are incorrectly matched with the wrong birth province or birth year, causing their tropical cyclone exposure to be mismeasured. Finally, the use of the tropical cyclones' immediate tracks i.e., the paths 0 km from the cyclones' centers as the measure of exposure may not accurately reflect individuals' actual experience given spatial differences among localities (land area) and between tropical cyclones (varying levels of wind radii). These threats to identification are discussed further and addressed in Section VI.

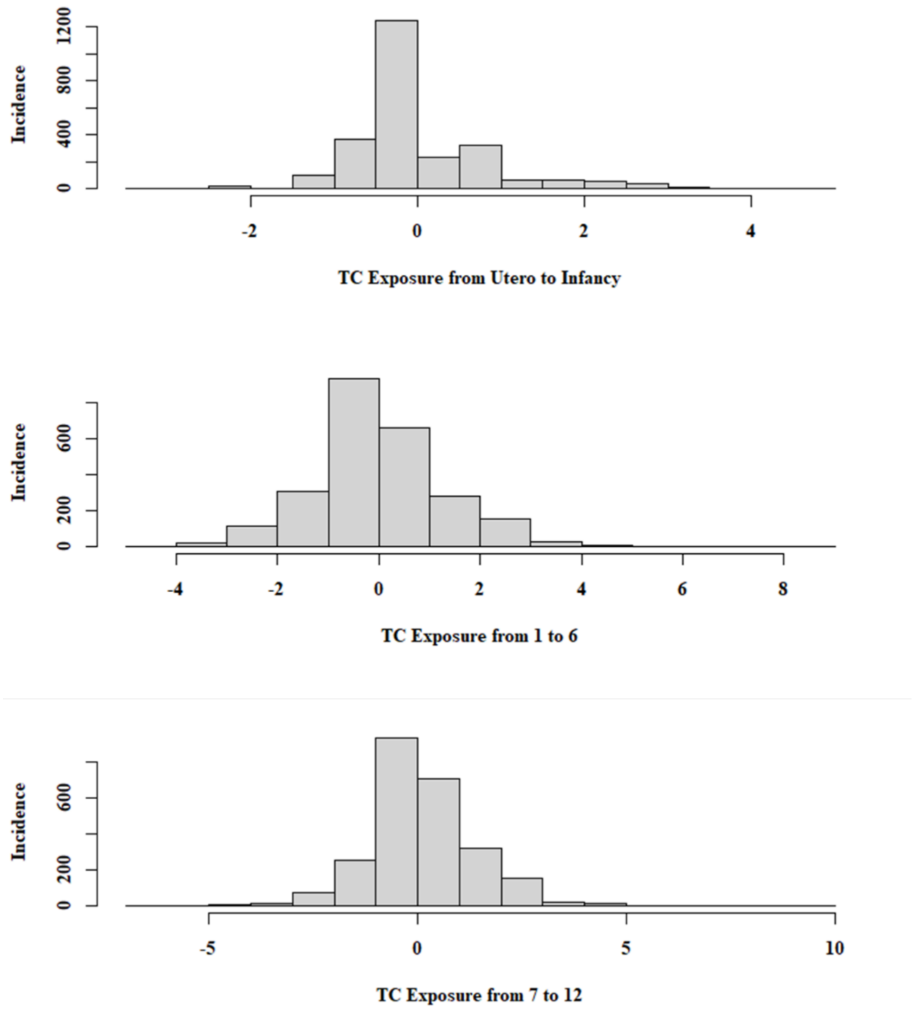

Figure 3. Histograms of Tropical Cyclone Exposure Deviation in Utero and Infancy (Top), in Early Childhood (Middle), and in Late Childhood (Bottom)

V. Results

Table 2 depicts the estimation results for the model in Equation (1). Based on Column (1), people who had been exposed to more tropical cyclones during in utero and infancy are more likely to believe that their intelligence is fixed and cannot be changed. These findings are consistent with Barker's fetal origins hypothesis and are significant at the five percent level. However, it appears that exposure to tropical cyclones in early childhood and late childhood do not have any significant impact on adult mindset. As is predicted by the psychological literature, men are more likely to hold growth mindsets than women (Dweck, 2013; Lloyd et al., 2005) and individuals' mindsets are uncorrelated with their parents' education levels (Haimovitz & Dweck, 2017).

Table 2. The Impact of Tropical Cyclone Exposure on Implicit Theories of Intelligence

	Implicit Theory of Intelligence		
	All Respondents	Female Subset	Male Subset
	(1)	(2)	(3)
TC Exposure from Utero to Infancy	0.092	0.086	0.092
	(0.038)**	(0.057)	(0.053)*
TC Exposure from 1 to 6	0.023	0.015	0.021
	(0.025)	(0.037)	(0.034)
TC Exposure from 7 to 12	-0.020	-0.031	0.004
	(0.024)	(0.038)	(0.032)
Male	-0.657		
	(0.053)***		
Mother's Education	-0.007	-0.006	-0.026
	(0.017)	(0.027)	(0.022)
Father's Education	-0.016	0.004	-0.021
	(0.017)	(0.027)	(0.023)
Observations	2,498	1,213	1,285

Notes: The coefficients of OLS are reported. The standard errors clustered at the provincial level are presented in parentheses. All regressions include fixed effects for birth province and year. *** p<0.01, ** p<0.05, * p <0.1.

Columns (2) and (3) present the heterogeneity of impact across genders. Upon preliminary inspection, it appears that intrauterine and infant tropical cyclone exposure leads men to hold fixed mindsets, but not women. This runs counter to what has been established in previous studies where women are more likely to be adversely affected by exogenous shocks (Datar et al., 2013; Maccini & Yang, 2009; Shoji, 2021).

To test the robustness of the empirical model, a rural subset was constructed by excluding respondents who were born or reside in the four districts of the National Capital Region and the provinces of Davao del Norte and Davao del Sur, identified by the National Economic and Development Authority (NEDA) as areas belonging in the metropolitan centers Metro Manila and Metro Davao, respectively (NEDA, 2020). The summary statistics of the consequent subset with 1,588 observations is presented in Table A1. Meanwhile, their geographic distribution is illustrated in Figure A2.

Running the regression on the rural subset leads to the results presented in Table 3. The main findings in Column (1) remain as robust as those of Table 2. Tropical cyclone exposure from in utero to infancy still lead to fixed mindsets in rural adults while tropical cyclone exposure in latter stages of childhood continue to be uncorrelated to ITI. Meanwhile, Column (2) reveals that experiencing more tropical cyclones during in utero and infancy leads rural women to believe that their intelligence is fixed. At the same time, the magnitude of impact is relatively higher for rural women compared to those for the main (Table 2, Column (1)) and the general rural datasets. Such results are significant at the 10% level.

Table 3. The Impact of Tropical Cyclone Exposure on Implicit Theories of Intelligence

	Implicit Theory of Intelligence		
	Rural Subset	Rural (Female)	Rural (Male)
	(1)	(2)	(3)
TC Exposure from Utero to Infancy	0.100	0.119	0.068
	(0.041)**	(0.062)*	(0.056)
TC Exposure from 1 to 6	0.020	0.013	0.009
	(0.027)	(0.041)	(0.036)
TC Exposure from 7 to 12	-0.034	-0.028	-0.015
	(0.026)	(0.042)	(0.033)
Male	-0.698		
	(0.066)***		
Mother's Education	0.006	-0.029	0.012
	(0.021)	(0.033)	(0.027)
Father's Education	-0.011	0.005	-0.010
	(0.021)	(0.033)	(0.027)
Observations	1,588	791	797

Notes: The coefficients of OLS are reported. The standard errors clustered at the provincial level are presented in parentheses. All regressions include fixed effects for birth province and year. *** p<0.01, ** p<0.05, * p <0.1.

VI. Threats to Identification

As briefly discussed in Section IV, the above estimation results may be confounded due to potential threats such as sample selection and measurement errors concerning the respondents' birth province and year as well as their tropical cyclone experience. These issues will be addressed in detail here.

A. Sample Selection

It has been established that extreme weather events like tropical cyclones are associated with increased risk of mortality, including stillbirths and child mortality, and patterns of migration (Deschênes & Moretti, 2009). This suggests that people who had been affected by the deviations in tropical cyclone exposure are more likely to be excluded from the sample.

Using data from the Philippine Population Census in 2015, it is first tested whether annual tropical cyclone shocks negatively impact population size. If increased exposure to tropical cyclones leads to mortality and migration, then these shocks should be negatively correlated with provincial population sizes. Regressing population size aggregated according to province and age on the tropical cyclone shocks together with the birth year and birth province fixed effects leads to the results depicted in Table A2. It appears only tropical cyclone exposure from ages seven to twelve results to significant reductions in population sizes.

Second, it is possible to observe whether these patterns of mortality and migration cause selection into the sample by running the above regression using the birth year and province cohort sizes from the sample. Similar to the previous hypothesis, if there is sample selection, then tropical cyclone exposure during in utero and infancy should have a significantly negative impact on the number of observations from each group.

Table A3 depicts the results of this configuration. Coefficients for tropical cyclone exposure in early childhood are significantly negative across genders suggesting that the non-robust findings for the respective variable in Table 1 may be confounded.

To test the robustness of these results, the new specification is ran using various subsets of the sample. First, utilizing the rural subset leads to the findings depicted in Table A4. Although the coefficients remain significantly negative for tropical cyclone exposure from ages one to six in the general and male cohorts, the impact of intrauterine and infant tropical cyclone exposure on rural cohort sizes are also insignificant.

Second, as evidenced by Table A5, it appears that findings are similar when the model is performed using the subset comprising only the respondents with ages below 50, a demographic which is expected to have had better adaptation and recovery mechanisms at their disposal. In addition, the impact of tropical cyclone exposure in late childhood on cohort size across all groups are now significantly negative at the one percent level for the main subset and five percent for both female and male subsets, respectively.

Finally, the test is also conducted using the non-migrant subset, which excludes those whose birth provinces cannot be identified due to the lack of formal schooling. According to Table A6, results are similar to those of the regression using the rural subset: the impact of tropical cyclone exposure in early childhood are significantly negative across genders, now including the female subset, while experiencing tropical cyclones during in utero and infancy is uncorrelated with cohort sizes.

The sample selection issue implies that tropical cyclone exposure would have a significantly negative impact on the number of respondents from each cohort. This effect should be more salient in the rural and the non-migrant subgroups, and less so in the subset of those with ages below 50. Higher mortality is expected both in rural areas and in earlier periods as disaster prevention and healthcare infrastructure are less developed for these. At the same time, assuming exposure to more tropical cyclones forces populations to migrate elsewhere, the negative impact of tropical cyclone exposure should be more robust in the non-migrant group. However, tropical cyclone exposure from in utero to infancy is uncorrelated to cohort sizes in all three subsets. Therefore, the results of the above tests suggest that sample selection into the dataset may not be severe, if any, and may simply be due to sampling variation.

Although these tests show that potential sample selection in the datasets is not severe, they do not necessarily dispute previous studies which show that natural disasters are associated with increased child mortality and migration. Of particular note is the inclusion of moderate shocks in the IBTrACS dataset. Whereas previous studies emphasize the effects of devastating natural disasters, the present study also comprises the effects of “weak” tropical cyclones such as tropical storms. These are only marginally stronger than tropical depressions, recording maximum sustained winds of 62 to 88 km/h, and may not be devastating enough on average to adversely affect mortality and migration patterns.

B. Measurement Error

The identification strategy may also be susceptible to issues regarding measurement error. First, the inclusion of the 576 respondents without formal education may lead to the mismeasurement of their tropical cyclone exposure if they are incorrectly matched with the wrong birth province, thereby resulting to attenuation bias.

To test this, the estimation model in Equation (1) is ran using the non-migrant subset defined in the previous subsection. This leads to outcomes similar to those found in the benchmark specification. According to Table A7, non-migrants who had been exposed to more tropical cyclones from in utero to infancy are still more likely to hold fixed mindsets. Counterintuitively, tropical cyclone exposure in late childhood is shown to lead to growth mindsets, albeit at a smaller magnitude, and higher levels of maternal education result to fixed mindsets. It is important to note that while this test mitigates measurement error, it results to sample selection by excluding respondents who may have been uneducated due to their exposure to tropical cyclones. The main results in Table 1 and the above-detailed results in Table A7 are both presented to highlight the robustness of the findings on tropical cyclone exposure during in utero and infancy regardless of specification.

Second, there is a tendency for older respondents in poor countries to misreport their age. This would result to some mismeasurement in the tropical cyclone exposure variables, potentially muddling the primary results of this study. As per Table A8, estimating Equation (1) on the subset of respondents with ages below 50 shows that findings are not qualitatively different for the subset that is more likely to report their correct age.

Finally, problems may also arise from the measurement of the tropical cyclone deviation variables, particularly in the use of the tropical cyclone's immediate tracks i.e., the direct paths of the tropical cyclones, 0 km from their centers or eyes. It is possible that such a construction may not accurately reflect the actual tropical cyclone experience of provinces given spatial differences among localities (i.e., land area) and between tropical cyclones (i.e., varying wind strengths across cyclone radii).

A study by Chavas et al. (2016) finds that the mean r_{12} (the radius wherein wind speed starts to fall below 12 km/h) for tropical cyclones in the Western Pacific basin is 381.8 km. However, other radii such as the radius of maximum winds (RMW) and the radius of gale-force winds (r_{34}), wind structures most relevant to studying the destructiveness of tropical cyclones (Knaff, 2006), have been mostly inconsistently measured and subjective to the respective operational agency measuring them (Song & Klotzbach, 2016). This has led previous studies to use benchmark radii in studying the impact of tropical cyclones ranging from 182 km (J. P. Kossin et al., 2007) to a more conservative measure of 250 km (Hsiang, 2010).

To address measurement error concerns, two sets of alternative tropical cyclone shock variables are generated by rendering the tropical cyclone tracks with "radii of effect" of 182 km and 250 km outside their direct paths, constructing the same tropical cyclone frequency index through a spatial join algorithm in GIS software, and computing for the resulting province-year tropical cyclone frequency shocks.

The model in Equation (1) is then estimated using these alternative tropical cyclone shock variables, the results for which are depicted in Table A9. Based on Columns (2) and (3), adult mindset is uncorrelated to wider measures of tropical cyclone exposure across all periods. Adult ITI appears to be most sensitive to direct tropical cyclone exposure during in utero and infancy, suggesting that negative effects to adult outcomes are more likely to manifest when individuals had been exposed just outside the tropical cyclone's eyewalls where winds and rainfall are the strongest and most devastating.

VII. Discussion

In Section II-D, two hypotheses were presented regarding *how* early life tropical cyclone exposure could lead to fixed mindsets in adults. First, education appears to be the most crucial channel for mindset formation. Cyclone shocks often cause damage to infrastructure and private property which may result to school closures, adjusted academic calendars, and absence or non-enrolment of affected children due to household budget reallocation. At the same time, income losses attributed to tropical cyclones may cause parents to experience stress, allocate time away from their family, and not be involved in their children's education. Since the psychological literature emphasizes both access to educational resources and parental involvement as essential to motivating children and teaching them to value the learning process, tropical cyclones' impact on overall educational attainment may also lead to fixed mindsets. Second, because children with poor health are less likely to receive necessary parental investments e.g., breastfeeding and children's perception of their health are greatly associated with their self-beliefs about intelligence and ability, children deprived of nutrition and healthcare because of tropical cyclone exposure during critical periods may also be prone to holding fixed mindsets.

Suggestive evidence regarding the plausibility of these channels may be found by estimating the benchmark model in Equation (1) using indicators for education and health as dependent variables, the same controls for gender and parents' education, and birth year and province fixed effects. If any of these two are pathways of influence, then their indicators must also be negatively correlated with tropical cyclone shocks during in utero and infancy which has been previously identified to be significantly associated with fixed mindsets in adults. To check for robustness, these tests are conducted using the main dataset and the rural subset.

Although the STEP survey does not include retrospective data on either a) education history i.e., whether respondents had to stop attending classes at any point other than their final schooling year or b) the degree of motivation individuals received from their parents' involvement in their studies, the first hypothesis may be tested by examining how tropical cyclone shocks impact educational attainment and high school completion. If tropical cyclones affect individuals' access to education and prevent their parents from being involved in their learning, then these must negatively impact overall educational attainment too. However, because ITIs themselves have been found to be strong predictors of academic performance, such a design is susceptible to reversal causality i.e., it may be possible that it is the individuals' mindsets that affect schooling years. Therefore, significant results, if any, must be taken as merely suggestive of the potential effect of tropical cyclone exposure to education access and parental motivation.

Table 4 presents the results for the above estimation model. Based on column (1), it appears that more tropical cyclone exposure from in utero to infancy increases schooling years. Counterintuitively, it appears that maternal educational attainment negatively affects respondents' schooling years. However, column (2) shows that both are uncorrelated with high school completion, putting into question the robustness of the former results. Findings using the rural subset in columns (3) and (4) also show no significant association between educational attainment and the experience of tropical cyclones at any point in early life. Furthermore, if access to educational resources and parental involvement in education are pathways toward fixed mindsets, more cyclone exposure during schooling years i.e., late childhood from ages seven to twelve should lead to fixed mindsets; that is not the case. Thus, education as a pathway is deemed implausible.

Table 4. The Impact of Tropical Cyclone Exposure on Educational Attainment

	Dependent variable:			
	Main Dataset		**Rural Subset**	
	Years of education completed	Completed High school or equivalent	Years of education completed	Completed High school or equivalent
	(1)	(2)	(3)	(4)
TC Exposure from Utero to Infancy	0.299	-0.004	0.249	0.015
	(0.154)*	(0.064)	(0.167)	(0.070)
TC Exposure from 1 to 6	0.005	0.051	-0.027	0.036
	(0.099)	(0.041)	(0.108)	(0.045)
TC Exposure from 7 to 12	0.044	0.028	0.031	0.040
	(0.097)	(0.041)	(0.104)	(0.044)
Male	0.274	0.037	0.316	0.038
	(0.215)	(0.091)	(0.269)	(0.114)
Mother's Education	-0.584	-0.002	-0.651	0.004
	(0.068)***	(0.029)	(0.084)***	(0.036)
Father's Education	-0.073	0.025	-0.076	-0.006
	(0.069)	(0.030)	(0.085)	(0.037)
Observations	2,498	2,498	1,588	1,588

Notes: The coefficients of OLS are reported. The standard errors clustered at the provincial level are presented in parentheses. All regressions include fixed effects for birth province and year. *** p<0.01, ** p<0.05, * p <0.1.

It is important to note that the results of this test do not necessarily dispute previous findings which associate experiencing tropical cyclones with lower educational attainment. As mentioned in Section VI-A, moderate shocks such as tropical storms are included in this study's dataset and frequent exposure to these appear to not have any long-term effects on education. However, the studies of Deuchert and Felfe (2015) and Herrera-Almanza and Cas (2021) investigate exposure to super typhoons whose destructive capacity have expectedly more obstinate and debilitating effects.

The second hypothesis may likewise be tested by estimating the effect of the exposure to early life tropical cyclones on adult health outcomes such as height, body mass index classification e.g., being underweight or obese, and self-reporting of chronic disease and number of days inactive due to illness. Regression results are depicted in Table 5. First, it appears that tropical cyclone exposure during in utero to infancy leads to lower adult height in both the main dataset and the rural subset as well as the reporting of more days of inactivity due to illness in the latter subgroup. Second, early childhood cyclone exposure has also been found to increase the likelihood of rural adults becoming underweight. Finally, the reporting of more days of inactivity is also observed to be significantly correlated with tropical cyclone exposure during late childhood in the rural subset.

As it has been established in Section V that only the exposure to tropical cyclones during in utero and infancy is significant to the formation of fixed mindsets in adults, the effects of intrauterine and infant tropical cyclone exposure to adult height and the self-reporting of inactive days due to illness are of key importance. Because adult height is a strong predictor of nutrition and resource availability before age five (Fogel, 1994; Maccini & Yang, 2009; Schultz, 2002, 2005; Steckel, 1995; Strauss & Thomas, 1998), these results provide evidence that tropical cyclones adversely impact individuals' nutritional intake, health development, and programming during their mothers' pregnancy and their infancy. Therefore, because conditions in these critical periods are robustly linked with key health development outcomes and children's perceptions of their own health are likewise strongly associated with their implicit beliefs about their ability or intelligence, it is plausible that childhood health is the underlying mechanism through which the exposure to more tropical cyclones during in utero and infancy leads to fixed mindsets in adults.

Table 5. The Impact of Tropical Cyclone Exposure on Health Outcomes

	Dependent variable:									
	Main Dataset					**Rural Subset**				
	Height	Chronic	Underweight	Obese	Days Inactive (in the last four weeks)	Height	Chronic	Underweight	Obese	Days Inactive (in the last four weeks)
	(1)	(3)	(4)	(5)	(6)	(7)	(9)	(10)	(11)	(12)
TC Exposure from Utero to Infancy	-0.718	0.134	0.041	0.077	0.095	-0.707	0.129	-0.021	0.085	0.126
	(0.321)**	(0.082)	(0.098)	(0.083)	(0.058)	(0.338)**	(0.091)	(0.105)	(0.094)	(0.067)*
TC Exposure from 1 to 6	-0.050	0.027	0.056	0.011	-0.026	-0.046	0.032	0.114	0.019	-0.020
	(0.207)	(0.053)	(0.062)	(0.054)	(0.038)	(0.218)	(0.058)	(0.068)*	(0.060)	(0.043)
TC Exposure from 7 to 12	-0.193	0.015	0.015	0.060	0.054	-0.160	0.035	-0.017	0.069	0.069
	(0.204)	(0.052)	(0.062)	(0.053)	(0.037)	(0.211)	(0.057)	(0.067)	(0.058)	(0.042)*
Male	7.684	0.034	0.054	0.068	-0.004	8.287	0.230	-0.044	0.152	0.071
	(0.448)***	(0.118)	(0.141)	(0.113)	(0.081)	(0.544)***	(0.150)	(0.173)	(0.147)	(0.109)
Mother's Education	0.164	0.006	0.021	0.002	0.018	0.008	0.023	-0.007	0.018	0.008
	(0.143)	(0.038)	(0.043)	(0.036)	(0.026)	(0.169)	(0.046)	(0.052)	(0.045)	(0.034)
Father's Education	-0.020	-0.010	0.026	-0.019	-0.009	0.018	-0.020	-0.008	-0.010	-0.041
	(0.144)	(0.038)	(0.044)	(0.037)	(0.026)	(0.171)	(0.046)	(0.053)	(0.046)	(0.034)
Observations	2,498	2,498	2,498	2,498	2,498	1,588	1,588	1,588	1,588	1,588

Notes: The standard errors clustered at the provincial level are presented in parentheses. All regressions include fixed effects for birth province and year. *** p<0.01, ** p<0.05, * p <0.1.

VIII. Conclusion

This study reveals that exposure to adverse conditions – in this case frequent exposure to tropical cyclones – during in utero and infancy leads individuals to believe that their intelligence or ability is fixed and cannot be developed even in adulthood. This effect is observed to be more pronounced in rural women and not in rural men. Additional robustness checks show that the impact is salient even among those who did not leave their birth provinces despite exposure (non-migrants) as well as individuals who are younger than 50 years old i.e., those who were more likely to have had better adaptation and relief mechanisms at their disposal. Furthermore, the long-term impact on adult ITI is most significant when individuals had lived closer to the path of tropical cyclones' eyewalls where rainfall and wind speeds are known to be most devastating.

The effects of tropical cyclones on maternal, fetal, and infant health appear to be the most plausible pathway of influence. Educational attainment as an underlying mechanism is precluded primarily because only the effect of tropical cyclone exposure during in utero and infancy i.e., before school age is significant to mindset formation. However, it is important to note that these results may be vulnerable to reverse causality issues and are meant to be taken as merely suggestive. It is thus recommended that further research tests these pathways directly.

As it stands, it is difficult to contextualize the estimated impact given the lack of studies on adult ITI and its association with other adult outcomes. However, the national growth mindset experiment conducted in the United States may provide some insight. Yeager et al. (2019) find that an intervention which teaches growth mindsets increases the inclination of poor-performing students toward growth mindsets by 0.38 and improves their grade point average (on a scale of zero to four) by 0.10. Such an intervention, they estimate, would support 5.3% of previously poor-performing students to avoid failure and allow them to graduate. Given that access to quality education is more deficient in developing countries, rural women's exposure to 3.22 additional tropical cyclones during in utero and infancy, without policy intervention, should have a greater contrasting effect i.e., higher prevalence of fixed mindsets, increased likelihood of academic failure, and lower educational attainment which consequently may lead to poorer adult health and lower socio-economic status. However, these remain to be conjectures primarily due to the preclusion of education as a pathway of influence in the study. It is hoped that future studies in both economics and psychology would expand on the understanding of fixed adult mindsets and their significance.

Nevertheless, three policy implications can be taken from the above results. First, due to their frequency, tropical cyclones should already be a primary consideration in household budgets (Anttila-Hughes & Hsiang, 2013). However, the continued observance of both short-term and long-term impact suggests that adaptation and recovery mechanisms remain to be costly or inaccessible. Given the overwhelming evidence that more favorable critical period conditions are vital to long-term human development, policymakers are called to improve access to and prioritize childcare and maternal health in disaster risk reduction and recovery programs. Second, this study highlights how anthropogenic climate change is a globalized systemic risk with far-reaching temporal and spatial consequences (Goldin & Mariathasan, 2014). As tropical cyclones and other climatic disasters continue to intensify due to global warming, the importance of concerted climate action from the global community is expressed not only to deter climate change, but also to eradicate poverty and inequality. Finally, at the local level, the adage "the Filipino spirit is waterproof" has been ingrained into national consciousness since it was first coined in 2012 after Typhoon Gener (internationally known as Typhoon Saola) devastated Northern Philippines. The mantra was coined to echo the myth of "Filipino resilience": that no matter how many deluges, floods, and landslides affected the disaster-prone country, its population would always survive and recover. This study shows that survival comes with latent and debilitating costs that could otherwise be avoided if structural improvements were set in place.

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Appendix

Table A1. Summary Statistics (Rural Subset)

Statistic	N	Mean	St. Dev.	Min	Max
TC Exposure from in Utero to Infancy	1,588	0.015	0.904	-3.061	4.727
TC Exposure from 1 to 6	1,588	-0.057	1.420	-4.182	8.182
TC Exposure from 7 to 12	1,588	0.087	1.460	-6.182	9.818
Implicit Theory of Intelligence	1,588	2.809	1.412	1	6
Male	1,588	0.502	0.500	0	1
Age	1,588	36.882	12.787	15	64
Year of Birth	1,588	1,977.435	12.777	1,950	2,000
Non-migrant	1,213	1.000	0.000	1.000	1.000
Mother's Education	1,588	1.351	1.741	0	4
Father's Education	1,588	1.638	1.778	0	4
Years of Education Completed	1,588	8.081	5.428	0	19
Completed High School or Equivalent	1,588	0.599	0.490	0	1
Height	1,588	159.256	11.721	122	183
Weight	1,588	62.169	14.431	25	111
Chronic Disease	1,588	0.155	0.362	0	1
Underweight	1,588	0.107	0.309	0	1
Obese	1,588	0.157	0.364	0	1
Days Inactive Due to Illness (last four weeks)	1,588	0.797	2.088	0	14
Employed Full-Time	1,588	0.308	0.462	0	1
Self-employed	1,588	0.212	0.409	0	1
Unemployed	1,588	0.076	0.265	0	1
Bank Account Ownership	1,588	0.301	0.459	0	1
Low Socio-economic Status	1,588	0.234	0.424	0	1
Mid Socio-economic Status	1,588	0.616	0.487	0	1
High Socio-economic Status	1,588	0.150	0.357	0	1
Health Insurance Ownership	1,588	0.616	0.487	0	1

Table A2. OLS Regression of Provincial Population Size on Tropical Cyclone Exposure

	Dependent variable:		
	Population Size	Population Size (Female)	Population Size (Male)
	(1)	(2)	(3)
TC Exposure from in Utero to Infancy	66.980	32.861	34.119
	(92.926)	(45.422)	(47.725)
TC Exposure from 1 to 6	-64.219	-27.867	-36.352
	(57.921)	(28.312)	(29.747)
TC Exposure from 7 to 12	-240.135	-114.057	-126.078
	(57.554)***	(28.132)***	(29.558)***
Mean dependent variable	14,547	7,175	7,371
Provinces[a]	87	87	87
Years	51	51	51
Observations	4,437	4,437	4,437

Notes: The coefficients of OLS are reported. The standard errors clustered at the provincial level are presented in parentheses. All regressions include fixed effects for birth province and year. *** p<0.01, ** p<0.05, * p <0.1.
[a] Provinces include all 81 administrative provinces, the four districts of the National Capital Region, and the cities of Isabela and Cotabato.

Table A3. OLS Regression of Sample Size on Tropical Cyclone Exposure

	Dependent variable:		
	Cohort Size	Cohort Size (Female)	Cohort Size (Male)
	(1)	(2)	(3)
TC Exposure from in Utero to Infancy	-0.039	-0.036	-0.003
	(0.036)	(0.024)	(0.024)
TC Exposure from 1 to 6	-0.067	-0.024	-0.043
	(0.023)***	(0.015)	(0.015)***
TC Exposure from 7 to 12	-0.019	-0.014	-0.005
	(0.023)	(0.015)	(0.015)
Mean dependent variable	1.256	0.646	0.610
Provinces	39	39	39
Years	51	51	51
Observations	1,989	1,989	1,989

Notes: The coefficients of OLS are reported. The standard errors clustered at the provincial level are presented in parentheses. All regressions include fixed effects for birth province and year. *** p<0.01, ** p<0.05, * p <0.1.

Table A4. OLS Regression of Sample Size on Tropical Cyclone Exposure (Rural Subset)

	Dependent variable:		
	Cohort Size	Cohort Size (Female)	Cohort Size (Male)
	(1)	(2)	(3)
TC Exposure from in Utero to Infancy	-0.029	-0.016	-0.013
	(0.028)	(0.018)	(0.019)
TC Exposure from 1 to 6	-0.039	-0.011	-0.028
	(0.018)**	(0.012)	(0.012)**
TC Exposure from 7 to 12	-0.003	-0.011	0.008
	(0.017)	(0.012)	(0.012)
Mean dependent variable	0.798	0.398	0.401
Provinces	39	39	39
Years	51	51	51
Observations	1,989	1,989	1,989

Notes: The coefficients of OLS are reported. The standard errors clustered at the provincial level are presented in parentheses. All regressions include fixed effects for birth province and year. *** p<0.01, ** p<0.05, * p <0.1.

Table A5. OLS Regression of Sample Size on Tropical Cyclone Exposure (Ages Below 50 Subset)

	Dependent variable:		
	Cohort Size	Cohort Size (Female)	Cohort Size (Male)
	(1)	(2)	(3)
TC Exposure from in Utero to Infancy	-0.044	-0.028	-0.016
	(0.038)	(0.023)	(0.024)
TC Exposure from 1 to 6	-0.106	-0.046	-0.060
	(0.024)***	(0.015)***	(0.015)***
TC Exposure from 7 to 12	-0.067	-0.033	-0.034
	(0.024)***	(0.014)**	(0.015)**
Mean dependent variable	1.005	0.490	0.514
Provinces	39	39	39
Years	51	51	51
Observations	1,989	1,989	1,989

Notes: The coefficients of OLS are reported. The standard errors clustered at the provincial level are presented in parentheses. All regressions include fixed effects for birth province and year. *** p<0.01, ** p<0.05, * p <0.1.

Table A6. OLS Regression of Sample Size on Tropical Cyclone Exposure (Non-migrant Subset)

	Dependent variable:		
	Cohort Size	Cohort Size (Female)	Cohort Size (Male)
	(1)	(2)	(3)
TC Exposure from in Utero to Infancy	-0.022	-0.029	0.007
	(0.031)	(0.021)	(0.021)
TC Exposure from 1 to 6	-0.058	-0.022	-0.036
	(0.019)***	(0.013)*	(0.013)***
TC Exposure from 7 to 12	-0.005	-0.004	-0.0003
	(0.019)	(0.013)	(0.013)
Mean dependent variable	0.966	0.473	0.493
Provinces	39	39	39
Years	51	51	51
Observations	1,989	1,989	1,989

Notes: The coefficients of OLS are reported. The standard errors clustered at the provincial level are presented in parentheses. All regressions include fixed effects for birth province and year. *** p<0.01, ** p<0.05, * p <0.1.

Table A7. The Impact of Tropical Cyclone Exposure on Implicit Theories of Intelligence (Non-migrant Subset)

	Implicit Theory of Intelligence
TC Exposure from Utero to Infancy	0.121
	(0.044)***
TC Exposure from 1 to 6	0.043
	(0.028)
TC Exposure from 7 to 12	-0.049
	(0.027)*
Male	-0.585
	(0.061)***
Mother's Education	0.062
	(0.021)***
Father's Education	0.011
	(0.020)
Observations	1,922

Notes: The coefficients of OLS are reported. The standard errors clustered at the provincial level are presented in parentheses. All regressions include fixed effects for birth province and year. *** p<0.01, ** p<0.05, * p <0.1.

Table A8. The Impact of Tropical Cyclone Exposure on Implicit Theories of Intelligence (Ages Below 50 Subset)

	Implicit Theory of Intelligence
TC Exposure from Utero to Infancy	0.100
	(0.043)**
TC Exposure from 1 to 6	0.026
	(0.030)
TC Exposure from 7 to 12	-0.007
	(0.028)
Male	-0.609
	(0.059)***
Mother's Education	0.000
	(0.018)
Father's Education	-0.013
	(0.018)
Observations	1,998

Notes: The coefficients of OLS are reported. The standard errors clustered at the provincial level are presented in parentheses. All regressions include fixed effects for birth province and year. *** p<0.01, ** p<0.05, * p <0.1.

Table A9. The Impact of Tropical Cyclone Exposure on Implicit Theories of Intelligence (with Varying Radii of Exposure)

	Dependent variable:		
	Implicit Theory of Intelligence		
	(1)	(2)	(3)
TC Exposure from Utero to Infancy (Direct Path)	0.092		
	(0.038)**		
TC Exposure from 1 to 6 (Direct Path)	0.023		
	(0.025)		
TC Exposure from 7 to 12 (Direct Path)	-0.020		
	(0.024)		
TC Exposure from Utero to Infancy (Within 182 KM)		-0.016	
		(0.018)	
TC Exposure from 1 to 6 (Within 182 KM)		0.009	
		(0.010)	
TC Exposure from 7 to 12 (Within 182 KM)		0.001	
		(0.011)	
TC Exposure from Utero to Infancy (Within 250 KM)			-0.030
			(0.024)
TC Exposure from 1 to 6 (Within 250 KM)			-0.002
			(0.011)
TC Exposure from 7 to 12 (Within 250 KM)			0.012
			(0.012)
Male	-0.657	-0.657	-0.661
	(0.053)***	(0.053)***	(0.053)***
Mother's Education	-0.007	-0.005	-0.005
	(0.017)	(0.017)	(0.017)
Father's Education	-0.016	-0.018	-0.017
	(0.017)	(0.017)	(0.017)
Observations	2,498	2,498	2,498

Notes: The coefficients of OLS are reported. The standard errors clustered at the provincial level are presented in parentheses. All regressions include fixed effects for birth province and year. *** p<0.01, ** p<0.05, * p <0.1.

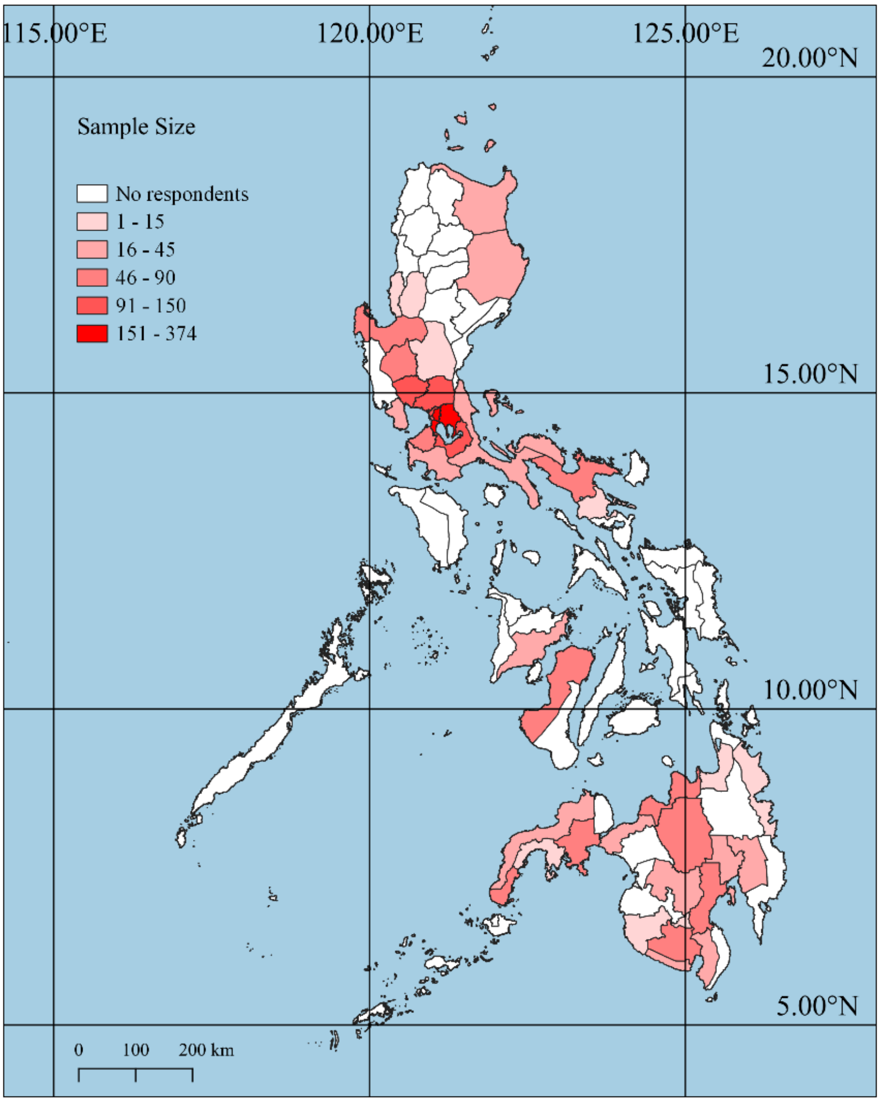

Figure A1. Geographical Distribution of the Sample derived from the Philippines – STEP Skills Measurement Household Survey 2015-2016

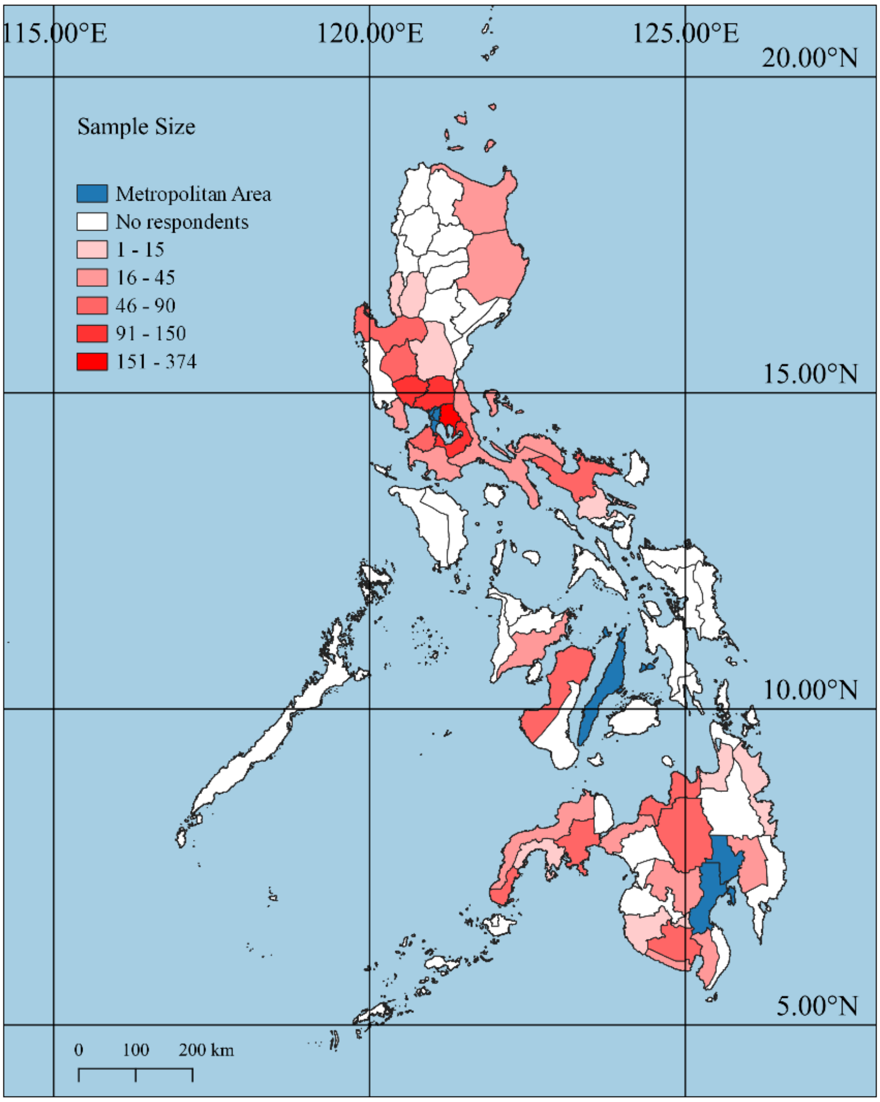

Figure A2. Geographical Distribution of the Philippines – STEP Skills Measurement Household Survey 2015-2016 Rural Sample