Fetal Origins of Mental Health: Evidence from Natural Disasters in Taiwan*

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Abstract

This paper examines the impact of poor intrauterine environment on psychological well-being later in life caused by severe typhoons that took place in Taiwan. Exploiting time and geographical variation, we compare the mental health of individuals who were exposed to severe typhoons while *in utero* in landfall counties to those who had no fetal exposure to severe typhoons. We find that the likelihood of mental disorders in adulthood resulting from fetal exposure to severe typhoons increased by 12%. The incidence of mood disorder (e.g. depression) and the use of antidepressant increased by more than 40%. The effects are more prominent for women.

Keywords: mental health, fetal origins, natural disasters
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1 Introduction

Mental illness affects hundreds of millions of people across the world. An estimated loss of global output associated with mental health conditions will reach $6 trillion in the next two decades, second only to cardiovascular diseases (Bloom et al. 2011). In 2004, one in four U.S. adults was estimated to experience some mental disorders (CDC 2011). Mental well-being is believed to be determined by various dimensions including individual characteristics, socioeconomic circumstances, and environmental factors (WHO 2012). Earlier studies document negative contemporaneous effects of adverse events on psychological well-being such as natural disasters (Edwards, Gray, and Hunter 2015; Shoaf et al. 2004), war and terrorist attacks (Brattia, Mendolab, and Mirandac 2014; Galea et al. 2003; Schlenger et al. 2002), and recession and job loss (Bradford and Lastrapes 2014; Currie and Tekin 2015; Kuhn, Lalive, and Zweimuller 2009; McInerney, Mellor, and Nicholas 2013). More recent medical literature proposes the "Neurodevelopment Hypothesis," which argues that poor fetal environment could cause damages to one's neural development, which in turn leads to mental illness later in life (Bennet and Gunn 2006).[1]

The objective of this study is to test this hypothesis; we would like to understand the impacts of poor prenatal environment on offspring mental health and related health care utilization. We exploit time and geographical variation to study the impact of *in utero* exposure to severe typhoons in Taiwan on the incidence of mental disorders, psychiatric drug use, and psychiatric-related health care utilization in adulthood. While Taiwan is hit by typhoons every summer, most of these typhoons cause limited damages. Thus, we focus our analysis using only severe typhoons, defined as causing more than 50 deaths, which occurred five times between 1958 and 1970. The basic idea is that the more severe typhoons would be associated with poorer prenatal environment, be it caused by maternal stress, lack of food or other reasons. The infrequent occurrence of severe typhoons allows us to compare those who are *in utero* during severe typhoons to those who are not *in utero* during severe typhoons while controlling for seasonality of birth. Additionally, a typhoon usually causes the most damage where it makes its landfall, and weakens drastically as it travels inland. Therefore, we can exploit this geographical variation to compare those in the landfall (high intensity) region to those in the non-landfall (low intensity) regions. Since we are studying those who are *in utero* during severe typhoons, presumably, the exact timing and landfall location of severe typhoons is somewhat unpredictable and could be exogenous to the decision to childbirth in a particular year and month.

[1] The hypothesized mechanism is through the elevation of the activity in maternal neuroendocrine systems (Phillips 2007). Some clinical studies show that fetal exposure to higher levels of maternal cortisol and prenatal stress are associated with increased social and affective problems and lower mental development (Buss et al. 2012; DiPietro et al. 2006; Huizink et al. 2003). For a review of the recent medical literature, please see Schlotz and Phillips (2009).

There are other recent empirical works that attempt to test this neurodevelopment hypothesis (Abel et al. 2014; Adhvaryu, Fenske, and Nyshadham 2014; Adhvaryu et al. 2015; Almond and Mazumder 2011; Class et al. 2013; Dinkelman 2015; Persson and Rossin-Slater Forthcoming; Maclean, Popovici, and French 2016). Most works rely on self-reported survey data on mental health (Adhvaryu, Fenske, and Nyshadham, 2014; Adhvaryu et al., 2015; Almond and Mazumder, 2011; Dinkelman, 2015; Maclean, Popovici, and French, 2016). As a paper by Bharadwaj, Pai, and Suziedelyte (2015) points out, survey measures on mental disorder suffer drastically from underreporting; thus, the estimation results from these papers may be biased. Another set of papers use hospital admission of psychiatric-related events as their main outcome (Os and Selten 1998; Watson et al. 1999; Abel et al. 2014; Class et al. 2013). As we show later in the paper, a very small share of the population (0.7%) has ever been hospitalized for psychiatric-related events, even though nearly 20% of population has ever been diagnosed with some mental disorder. These papers examine the extreme event of mental disorder. Some other papers, including Persson and Rossin-Slater (Forthcoming), use prescription data to identify mental illness. However, many medical papers suggest that the off-label use of psychiatric drugs is rampant (Radley, Finkelstein, and Stafford, 2006; Chen et al., 2006; Wittich, Burkle, and Lanier, 2012; Chien et al., 2007). For example, a drug approved for antipsychotic use being used to treat dementia (Leslie, Mohamed, and Rosenheck, 2009) or another drug approved to treat Alzheimer's disease being used to treat psychiatric disorders (Zdanys and Tampi, 2008). Additionally, for some psychiatric visits, no drug was ever prescribed. In our dataset, nearly 20% of individuals who had mental disorder-related visits were never prescribed psychiatric drugs. Therefore, using prescription data without the diagnosis code can mis-identify the incidence of mental illness.

There are features about Taiwan that make it a suitable case to test this hypothesis. The key feature is the availability of data. First, we use detailed health insurance claims records for all inpatient, outpatient, and prescription drug use of a 5 percent population sample (approximately 1 million individuals) drawn in 2000 to identify mental disorders. The claim records provide detailed physicians' diagnosis codes and drugs prescribed for each medical visit that is covered by the patient's insurance between 1998 and 2002. The ability to use a combination of inpatient, outpatient, and prescription drug records means that the identification of mental illness in our study is less susceptible to misreporting compared to the existing works. Second, the stigma attached to seeing a psychiatrist or the reluctance of seeking help for mental disorders is well documented in the medical literature, even in western countries (Barney et al., 2006; Schomerus, Matschinger, and Angermeyer, 2009). While visiting a psychiatrist is not common in Taiwan, we are able to identify psychiatric-related medical use from visits to psychiatrists and all other physicians. This is important since we find that in our sample 25% of antidepressants were prescribed by non-psychiatric physicians and the majority of those were prescribed by doctors in family medicine and internal medicine. This helps to alleviate under-reporting issues that may arise due to the social stigma attached to seeing a psychiatrist. Third, compared to most of the existing work, which focuses on one type of mental illness or uses self-reported questions focusing on mental health very broadly, we are able to study a wide range of mental illnesses (ranging from anxiety/personality disorder, which affects 15% of the population, to schizophrenia, which affects less than 1% of the population). Also, the dataset allows us to capture a full spectrum of mental illness severity, ranging from the less severe cases of those patients whose conditions required outpatient visits but were not severe enough to receive prescription drug treatment, to the most severe cases, in which individuals were admitted to psychiatric facilities long-term. Lastly, the universal health insurance coverage rate in Taiwan was more than 96%. The coverage is generous, and the copay for any medical visit is extremely low (ranging from $2-$3 when GDP per capita was about $21,000, in 2000). Therefore, we worry less about selection issues related to the affordability of psychiatric/medical visits.

Our analysis finds that the likelihood of mental illness and the use of psychiatric drugs increased by 2.4 percentage points (from the basis of 20 percentage points, roughly an 12% increase) for individuals who were exposed to severe typhoons while *in utero* in landfall counties relative to individuals who had no fetal exposure to severe typhoons. Those who were exposed to severe typhoons in non-landfall counties are only marginally affected. We analyze cases for the common disorders: anxiety and personality disorder, mood disorder, and schizophrenia.[2] We find that mood disorder, which includes depression and bipolar disorder, has the largest increase of 1.7 percentage points (the mean is 4 percentage points, roughly a 42% increase), and the use of antidepressants increases by 50% (the mean is 5 percentage points) among those who had *in utero* exposure to severe typhoons compared to those who never had exposure to a severe typhoon. We also find fetal exposure to a severe typhoon is associated with more psychiatric-related visits and higher psychiatric-related expenditures. Interestingly, we did not detect any significant difference in inpatient psychiatric admission, although it is probably due to the lack of statistical power since only less than 0.7% of the population has ever been admitted for inpatient treatment for mental illness. Another interesting finding is that the negative effects on mental health are almost exclusively found among women, but we cannot rule

[2] According to Kessler et al. (2005), the most common mental disorders are anxiety, mood and impulse control (personality disorder) in the US. We treat anxiety and personality disorders as one category since the health claims data used a different set of diagnostic codes prior to 2000, and only switched to ICD-9 (International Classification of Diseases) code in 2000. The older codes combined anxiety and personality disorders in one diagnostic code, so we are not able to distinguish them.

out whether this is due to either a positive selection on surviving males or a gender differences in health care-seeking behavior. The main findings are robust to several alternative specifications including using different measures of typhoon severity, restricting to subsamples to reduce doubts about the comparability of control and treatment groups, using alternative specifications that control for region-birth year fixed effects, and conducting placebo permutation tests. Lastly, using an event study specification, we find that *in utero* exposure has the greatest impacts on mental health compared to exposure in the first few years of life.

This study is relevant to a large body of literature that investigates the short- and long-term effects of exposure to poor intrauterine environment (see Almond and Currie 2011, Currie and Vogl 2013 and Aizer and Currie 2014 for a review). Although the literature has provided extensive evidence on the impacts on pregnancy outcomes, physical health, and human capital formation, the causal relationship of *in utero* environment and adult mental health is relatively under-studied due to the data limitations.[3] This paper contributes to the literature by documenting a causal relationship between poor prenatal environment and mental health in adulthood.

The paper is organized as follows. Section 2 describes the newly constructed severe typhoon dataset and the health insurance claim records. Section 3 outlines the empirical strategy, and section 4 presents the results. Section 5 discusses the mechanisms and concludes.

2 Data

2.1 Typhoon severity dataset

Taiwan is typically affected every summer by at least one typhoon. In general, a typhoon causes more damage when it first makes landfall, after which its structure weakens quickly. Therefore, having detailed data on each typhoon event is extremely crucial since it allows us to separate extreme typhoon events from regular ones, and also to identify high-intensity (landfall) regions from low-intensity (non-landfall) regions. The historical typhoon data used in this study is drawn from the Typhoon Database of the Central Weather Bureau and the 2014 Annual Disaster Report from the National Fire Agency. For each typhoon event, we have information on the date, landfall county, death toll, and property damage at the national level. The earliest year with detailed information is 1958.

[3] Here are some examples of the papers which find that maternal exposure to stressful environment is associated with worse birth and non-mental health outcomes (Aizer, Stroud, and Buka, 2015; Currie and Rossin-Slater, 2013; Simeonova, 2011; Lauderdale, 2006; Camacho, 2008; Mansour and Rees, 2012; Quintana-Domeque and Rodenas, 2014).

Even though the age of onset for most mental illnesses is the mid-twenties, there is often a delay between the onset and the first treatment (Kessler et al. 2007). Therefore, we focus on individuals who were born between 1959 and 1970 to allow some time to elapse in the 1998-2002 insurance claim dataset. During the period of 1959 to 1970, there were 119 typhoons, and 41 result in deaths. Figure 1 depicts death tolls for typhoons during this period. Each solid dot/hollow dot/plus represents the death toll for one typhoon. If there is more than one typhoon in a given year-month, only the one with the most deaths is depicted on this figure. In this study, we focus on only the typhoons causing more than 50 deaths; hereafter, we refer to them as severe typhoons. These are marked as dots in the figure. The solid dot represents those typhoons that made landfall, while hollow dots represent those typhoons that did not make landfall. In our main analysis, since we use the comparison of landfall counties to non-landfall counties as a first difference, the individuals who are exposed to those four severe typhoons that did not make landfall are coded as exposed in non-landfall counties.[4] To confirm that the results are not sensitive to the definition of severe typhoons, we also use alternative definitions for severity such as the number of collapsed buildings or changing the cutoff for the death tolls in the robustness section.

2.2 Health Insurance Claim Records

The second dataset used in this study includes detailed health insurance claim records of a 5 percent Taiwanese population sample (approximately 1 million individuals) drawn in 2000. Universal health insurance in Taiwan was first introduced in 1995, and the coverage rate was more than 96% within two years of implementation. The dataset has limited information on individual characteristics (i.e., gender, birth date), but it contains all outpatient and inpatient visits and drug prescriptions that were covered by universal health insurance between 1998 and 2002 for these individuals. International Classification of Diseases (ICD-9) codes were used to identify the reasons for each medical visit. Mental illness is identified if physicians diagnosed a mental disorder including psychoses, organic psychotic conditions, other psychoses, neurotic disorders, personality disorders, and other non-psychotic mental disorders.[5]

Drug prescriptions record contains information about the dispensed product, including

[4] As a robustness check, we use a specification that separates all three exposure statuses–the exposure to a severe typhoon in landfall counties, exposure to a severe typhoon in non-landfall counties, and the exposure to a non-landfall severe typhoon. The results of the latter two are not statistically different. Thus, we decide to combine these two exposure statuses for the sake of simplicity. The results are available upon request.

[5] See Appendix A.1 for a list of ICD-9 codes of mental disorders and categorization of the mental disorders that are examined in this study.

the compound name, quantity, mode of administration, and cost. Drugs are classified according to the hierarchical anatomic therapeutic chemical (ATC), which allows us to identify psychiatric drugs including antidepressants, antipsychotic, and anxiolytics. We code a patient as ever using psychiatric drugs if an ATC code of psychiatric drugs was recorded and the visit was psychiatric-related based on ICD-9 codes.[6]

In order to identify one's in utero exposure to a typhoon, we need information on one's place of birth. Unfortunately, the health insurance claim records do not contain the county of residence nor the county of birth for individuals. We first proxy the county of residence based on the county of each individual's most frequently visited outpatient hospital/clinic in 2000. However, county of residence might not be the same as county of birth if there is migration. Thus, to minimize the migration issue, we further restrict our sample to only those who currently reside in rural areas. The assumption here is that few people move into rural areas, so if we restrict our analysis to rural residents, we are less likely to mis-identify their birth counties.[7] We verify our assumption using the 2000 census—77% of rural residents stayed in their birth county as opposed to half of urban residents are residing in their birth county. As a robustness check, we also restrict our analysis to residents from areas with low in-migration rates.

Table 1 presents the summary statistics at the individual level for the period between 1998 and 2002. Overall, one in five individuals had a visit related to any mental illness during this period. The prevalence rate is comparable to more developed countries such as the United States and United Kingdom.[8] Despite a high prevalence rate, the average cost of psychiatric-related outpatient expenditures per person during these 5 years is only $61 (inflation adjusted to 2011 USD). This is a feature of Taiwan's single-payer health care system: total expenditure on health care is quite low compared to countries with multi-payer systems such as the United States. On average, individuals who were exposed to severe typhoons are slightly older because three out of five severe typhoons occurred in the first few years of the study periods. Those individuals who were exposed to severe typhoons while *in utero* and who were residing in landfall counties have the highest prevalence rates of mental disorders and highest usage of psychiatric drugs, followed by exposed individuals of non-landfall counties, with the unexposed individuals having the lowest prevalence rates. Prenatal exposure to severe typhoons in landfall counties

[6]The ATC system classification system is published by the World Health Organization Collaboration Center for Drug Statistics Methodology. It is very difficult to identify off-label drug use from the claim records; therefore, we follow the ATC classification for the primary use of drugs. See Appendix A.2 for a list of ATC codes that were used to identify psychiatric and other drugs.

[7]The administrative level for rural areas is township *(shiang)* as opposed to urban areas, which is city *(shi)*.

[8]The one-year prevalence rate of mental illness is 21.5% among U.S. adults aged between 26 and 49 in 2013 (Substance Abuse and Mental Health Services Administration 2014). Nearly 25% of British adults aged between 16 and 74 experienced a mental illness in a given year (Singleton et al. 2003).

is also associated with more health care utilization and expenditures. However, these differences may be due to factors other than fetal exposure to severe typhoons, such as age differences. In the next section, we will use regression analysis to estimate the causal effects of severe typhoons.

3 Empirical Strategy

The objective of this study is to estimate the long-term impacts of prenatal exposure to severe typhoons on mental health. In this section, we first present descriptive evidence of prenatal exposure to severe typhoons. In the second part, we discuss the empirical specification used to uncover the causal impacts of severe typhoons.

3.1 Descriptive Evidence

Figure 2 shows the prevalence of adult mental illness by year-month birth cohort and by *in utero* exposure to severe typhoon status. Prevalence of mental illness is aggregated to year-month of birth and separated by *in utero* exposure status. The dotted lines reflect the timing of severe typhoons. Immediately after the severe typhoon (the vertical dotted line), we see higher prevalent rates of mental illness among those who are in the landfall counties (solid dots). However, we do not observe this pattern in areas with no landfall (solid triangles), nor among those who never had *in utero* exposure to a severe typhoon (plus signs). Overall, the figure is suggestive of a relationship between prenatal exposure to severe typhoons and worse mental health.

3.2 Empirical Specification

In this study, we exploit two sources of variation, geographical variation of typhoon landfall location and the timing of severe typhoon, to examine the treatment effects of *in utero* exposure to severe typhoons on the likelihood of mental illness. As nature tends to be smooth and the location/timing of severe typhoons is unexpected, any deviation from a smooth trend that is sharply timed after the typhoon's landfall and especially pronounced in counties hardest hit by the typhoon would be interpreted as a causal effect of the typhoon. The key assumption of this approach is that the trends of the incidence of mental disorders would be similar in exposed and unexposed individuals had the severe typhoons not occurred.

Specifically, we compare the mental health of individuals who were exposed to severe typhoons while *in utero* in landfall counties and non-landfall counties to those who had no fetal exposure to severe typhoons, respectively. Those individuals who were not exposed to severe typhoons while *in utero* are the comparison group, and this group consists of cohorts who were older and younger than those in the treatment groups.

3.2.1 Main Specification

We first examine the likelihood of mental disorders and the use of psychiatric drugs as outcomes. For individual i born in year t and month m residing in county c, the primary specification is as follows:

$$\begin{aligned} Y_{icmt} = \alpha &+ \beta_1 * I(InUteroExposuretoSevereTyphoon)_{mt} * I(LandfallCounty)_{cmt} \\ &+ \beta_2 * I(InUteroExposuretoSevereTyphoon)_{mt} * I(Non-landfallCounty)_{cmt} \\ &+ \delta * Male_i + \delta_t + \zeta_m + \eta_c + \sum_c County_c * BirthYear_t + u_{icmt} \end{aligned} \tag{1}$$

We include county-, birth year-, and birth month-fixed effects to control for regional time-invariant determinants and time effects that are common across counties. $I(InUteroExposuretoSevereTyphoon)$ is an indicator variable, 1 if individual i was born within the first 252 days after the severe typhoon makes landfall.[9] $I(LandfallCounty)$ and $I(Non-landfallCounty)$ are indicator variables–whether individual i resides in the landfall or non-landfall county for the given severe typhoon. The estimate β_1 captures any differences in the prevalence of mental disorders between individuals who had no *in utero* exposure to a severe typhoon and those who reside in a landfall county and had *in utero* exposure to a severe typhoon. Similarly, the estimate β_2 captures the differences in the prevalence of mental disorders between individuals who had no *in utero* exposure to a severe typhoon and those who reside in a non-landfall county and had *in utero* exposure to a severe typhoon. β_1 and β_2 are interpreted as the total effects of a severe typhoon in landfall and non-landfall counties, respectively. Standard errors are clustered at the county level to allow for the possibility of within-county correlation.

It is also possible that different areas may have different trends in mental health outcomes; therefore, we take several approaches to address this concern. First, we include additional county-specific birth cohort linear trends. Second, in the robustness section, we present results controlling for region-specific birth cohort fixed effects.

We propose two predictions related to the estimates of interests, β_1 and β_2. First, based on early childhood literature, we would expect that a poor *in utero* environment

[9] It is possible that gestational length may have changed as a result of typhoon or poor intrauterine condition, but in our other work (Liu, Liu, and Tseng (2015)) and Torche (2011), we find that the impact of poor environment on gestational length is extremely small. One paper finds a change of 0.07 week and Torche (2011) finds a change of 0.1 week. Therefore, the extent of mis-identifying the *in utero* period is limited. We have also tried alternative specifications of using the first 8 months or the first 10 months after the typhoon, and the results remain robust. These results are available in web appendix.

may deteriorate mental health later in life. Thus, if a severe typhoon leads to worse adult mental health, then we would expect to find $\beta_1 > 0$. Second, the severe typhoon insults are going to be concentrated in the landfall county. Therefore, we would expect to see $\beta_1 - \beta_2 > 0$.

3.2.2 Special Considerations for Discrete and Continuous Outcomes (Number of Visits and Expenditures)

Estimates from Equation 1 would inform us whether *in utero* exposure to a severe typhoon could affect the prevalence of mental disorder at an extensive margin. We are also interested in examining the effect for other dimensions, such as psychiatric-related expenditures, the number of psychiatric-related medical visits, and the number of hospital bed-days in psychiatric wards as outcomes of interest.

A conventional approach to deal with the expenditure data, which is left-skewed with a long right tail, is to apply log transformation. Typically, one would assume some positive values to all observations (e.g., adding one to all observations to avoid dropping the observations with an observed value of zero). However, variance of the data would be distorted after this transformation. We overcome these problems by employing the inverse hyperbolic sine (IHS) transformation method. The transformation method was first introduced by Johnson (1949), and has been adopted in recent empirical economics literature (Gelber 2011; Hochguertel and Ohlsson 2009; Pence 2006; Chen 2013; Rotunno, Vezina, and Wang 2013).[10] There are a couple advantages of the IHS transformation method. First, the IHS function is defined even when the value is zero. Second, the interpretation of the regression coefficient is similar to standard log transformation since the transformed dependent variable $log(Y_{icmt} + (Y_{icmt}^2 + 1)^{0.5}$ is approximately $log(2y)$ or $log(2) + log(y)$ with exceptions for small values (Chen, 2013). Figure 3 displays the histograms of health care expenditures before and after applying the IHS transformation method. The empirical specification is of the following form:

$$
\begin{aligned}
Log(Y_{icmt}+(Y_{icmt}^2 + 1)^{0.5}) = \alpha & \\
& + \beta_1 * I(InUteroExposuretoSevereTyphoon)_{mt} * I(LandfallCounty)_{cmt} \\
& + \beta_2 * I(InUteroExposuretoSevereTyphoon)_{mt} * I(NonlandfallCounty)_{cmt} \\
& + \delta * Male_i + \delta_t + \zeta_m + \eta_c + \sum_c County_c * BirthYear_t + u_{icmt}
\end{aligned}
\tag{2}
$$

[10]See Burbidge, Magee, and Robb (1988) for a discussion on the advantage of inverse hyperbolic sine transformation.

Y_{icmt} represents the psychiatric-related expenditures for individual i born in year t and month m residing in county c. The estimate β_1 is interpreted as indicating that individuals who had prenatal exposure to severe typhoons are likely to have (100*β_1)% more psychiatric-related expenditures as compared to individuals who had no prenatal exposure.

The other two outcomes we are interested in are the number of psychiatric-related medical visits and the number of bed-days in psychiatric wards. The nature of a count variable such as number of visits is that it consists of non-negative integer values and are not normally distributed. For this type of data, more appropriate approaches to estimate the effects are the Poisson and negative binomial regression models. We will show the estimation results from both models.

3.2.3 Event Study (Timing of Exposure)

We employ event study specification to examine the impact of exposure to severe typhoons at various ages, specifically from two years before birth to three years after birth. By estimating age-specific effects of severe typhoon exposure, we can see whether the incidence of mental illness is more affected while *in utero*, and if the deviation from the smooth trend is indeed sharply timed after the typhoon incident. The specification is as follows:

$$\begin{aligned}
Y_{icmt} =& \alpha \\
&+ \sum_{x=-2}^{3} \beta_{1x} * I(AnyExposuretoSevereTyphoonatAgeX)_{mt} * I(LandfallCounty)_{cmt} \\
&+ \sum_{x=-2}^{3} \beta_{2x} * I(AnyExposuretoSevereTyphoonatAgeX)_{mt} * I(NonlandfallCounty)_{cmt} \\
&+ \delta * Male_i + \delta_t + \zeta_m + \eta_c + \sum_{c} County_c * BirthYear_t + u_{icmt}
\end{aligned} \tag{3}$$

The estimate β_{1x} captures the difference in mental illness in individuals who were exposed to severe typhoons at age x to individuals who were not exposed to severe typhoons at age x; x ranges from -2 to 3. The reference group consists of individuals who had no exposure to severe typhoons between two years before birth to three years after birth. These individuals include birth cohorts that are older or younger than the treatment groups.

4 Results

4.1 Mental Illness and Use of Psychiatric Drugs

The regression results from Equation 1 are shown in Table 2. Panel A presents the results from diagnosis while Panel B presents the results for psychiatric drug use. We find that the likelihood of being diagnosed with mental illness for those who were exposed to severe typhoons while *in utero* in a landfall county increases 2.4 percentage points (roughly an 12% increase) relative to individuals who did not have any prenatal exposure to severe typhoons.[11] Mental illness is a broad term that includes psychoses, organic psychotic conditions, other psychoses, neurotic disorders, personality disorders, and other non-psychotic mental disorders. In Columns 2-4 of Panel A, we break down mental illness into the three common mental disorders: anxiety and personality disorders, mood disorders, and schizophrenia. The results show an increase in the prevalence of anxiety and mood disorders, and schizophrenia increases by 0.4-1.9 percentage points as a result of prenatal exposure to a severe typhoon.[12] Another interesting point worth noting is that β_1 and β_2 are statistically different from each other at 10%. The impacts of severe typhoons are much more pronounced for exposed individuals of landfall counties relative to those residing in non-landfall counties, which also suggests that the main findings cannot simply be explained by unobserved secular changes between birth cohorts.

We further investigate the likelihood of psychiatric drug use in Panel B of Table 2. Individuals with *in utero* exposure to severe typhoons in landfall counties are 1.8 percentage points (roughly an 11% increase) more likely to use any psychiatric drugs as compared to unexposed individuals.[13] The results also indicate that the effects on psychiatric drugs are concentrated on the use of antidepressants, a 50% increase in the likelihood of using antidepressants. The impacts on use of anxiety and psychosis drugs are positive although the estimates are statistically insignificant.

Comparing the magnitude across different disorders, depression (mood disorder) seem to be most affected by the poor intrauterine environment. The diagnosis of mood disorder (which includes depression) increases by 42% (=0.017/0.04), and the use of antidepressants increases by 50% (=0.026/0.05) among those who had *in utero* exposure to severe

[11] Adhvaryu, Fenske, and Nyshadham (2014) find the likelihood of mental severe distress reduced by 3 percentage points (50% of the mean) resulting from a one standard deviation increase in cocoa price.

[12] Papers in the medical/psychiatric literature also find similar results. For example, a paper by Khashan et al. (2008); Brown et al. (2000a) finds that maternal stress or maternal infection is associated with increased risk for schizophrenia; Brown and his coauthors in a series of papers find evidence for increased risk of mood disorder (Brown et al. (2000b, 1995)).

[13] The magnitude is somewhat similar to the finding by Persson and Rossin-Slater (Forthcoming), who find a 0.7 percentage point increase (or 7-11% of the mean) in the use of anxiety and depression drugs resulting from prenatal bereavement.

typhoons compared to those who never had exposure to a severe typhoon.

4.2 Psychiatric-Related Health Care Utilization and Expenditures

We have shown the effects of severe typhoons on the incidence of mental illness. It is of interest to see if *in utero* exposure to severe typhoons also increases psychiatric-related visits and associated medical expenditures. Columns 1 and 2 of Table 3 present the estimation results from Poisson and negative binomial regression models, investigating the number of psychiatric-related visits. Although the Poisson variance assumption is not supported by the data, the estimation results from Poisson and negative binomial regression models are similar. The results show that prenatal exposure to severe typhoons in a landfall county is likely to increase the number of psychiatric-related outpatient visits by 35% (=exp(0.30)-1). We present the results from estimating Equation 2 in Columns 3 and 5 of Table 3. The results suggest that individuals who were exposed to severe typhoons in landfall counties would spend 12% more on total psychiatric-related outpatient care and 7.7% more on out-of-pocket psychiatric-related expenses.

In a regression not shown here, we examine the impact on more serious psychiatric events—such as hospital admission for a psychiatric-related event, a hospital bed-day, or a psychiatric-related inpatient expenditure. While the coefficients are positive, they are not statistically significant. It is likely that we do not have enough statistical power since only 0.7% of the individuals included in this sample have ever been hospitalized in a psychiatric ward or facility. These results are presented in the web appendix.[14]

4.3 Timing of Exposure

Although this study focuses on poor intrauterine environment, it is reasonable to ask whether exposures to severe typhoons at other ages also affects one's mental health later in life. Since the main finding is concentrated on women, we explore the effects of the timing of exposure to severe typhoons among women. Since three out of five severe typhoons occurred in consecutive years of the earlier period, it would prevent us from clearly identifying one's timing exposure to severe typhoon. In this part of the analysis, we focus on women who were born between 1964 and 1970 to avoid overlapping of severe typhoon exposure at different ages. Figure 5 presents the estimation results of Equation 3. First, the results provide some evidence that we find no effects on the exposure before the possible timing of the *in utero* periodtwo years before birth. It is certainly possible

[14]The null result on inpatient care is consistent with Abel et al. (2014) and Class et al. (2013), who also find little effects based on hospital admission data.

that those who were exposed to severe typhoons during early childhood is also affected by the destruction too, but as we can see the results are imprecise and are statistically insignificant. We should remind the readers that the "neurodevelopment hypothesis" is about the fact that maternal cortisol and prenatal stress could affect fetal neurodevelopment. While early childhood exposure to a severe typhoon may also affect one's outcome, it would not be through the same channel as the *in utero* exposure. In sum, although exposure to a severe typhoon at age one has some positive yet statistically insignificant effects on mental illness, exposure in the fetal life has the most striking impacts.

4.4 Heterogeneous Effects by Gender

We next probe whether the effects are different by gender. Table 4 presents the estimation results of Equations 1 and 2 by gender. Columns 2 and 4 show the estimates of β_1 for mental health outcomes for males and females, respectively. Overall, the results indicate that prenatal exposure to a severe typhoon has a larger impact on women.[15] There are a few possible explanations for why we find larger effects for females. First, we cannot rule out the possibility that women and men may have different health care-seeking behaviors. For example, both males and females experience the same depression symptoms but females may be more likely to report them to physicians. It is evident from the baseline differences in means. Additionally, early childhood literature suggests that weaker fetuses could be culled during pregnancy in the presence of adverse events; in particular, male fetuses are less likely to survive than female fetuses (Bozzoli, Deaton, and Quintana-Domeque 2009; Liu, Liu, and Tseng 2015; Gorgens, Meng, and Vaithianathan 2012; Bhalotra, Valente, and van Soest 2010). The literature would suggest that fetal exposure to severe typhoons is likely to increase mortality selection; therefore, on average a surviving male could be healthier than a surviving female. Lastly, with the same *in utero* shock, the negative effects on females may be reinforced by parental investment behavior under the practice of son preference that is prevalent in Taiwan.

4.5 Robustness of the Results

For the sake of simplicity, the rest of this section presents the robustness results only on the main outcome, the prevalence of mental illness, for female since there seem to be no significant impact on male. To see whether the baseline results are sensitive to the definition of severity, we use alternative proxies of severity of typhoons, and the results are presented in Table 5. Columns 2 and 3 of Table 5 consider different cutoffs of death

[15] This finding echoes the findings from Lavy, Schlosser, and Shany (2016); Maccini and Yang (2009); Field, Robles, and Torero (2009) that females are more suspectable to changes in intrauterine condition.

tolls, and columns 4 and 5 use numbers of collapsed buildings. The number of severe typhoon incidents vary under each alternative measure, ranging from four to eight. The results are robust to various definitions of severe typhoons.

Further, Table 6 examines the effects on various subgroups to verify that the impacts are not due to different characteristics between exposed and unexposed birth cohorts. First, Taiwan is an island and it is unusual for typhoons to make landfall in the north and central regions due to its location. Thus, Column 2 excludes regions that did not experience landfall of a severe typhoon between 1958 and 1970. Second, Figure 1 shows that since most of the severe typhoons occurred in earlier years, it appears that those who were exposed to severe typhoons are older than those who are not affected by severe typhoons. In Column 3, we exclude individuals who were born after 1966 to confirm that the impacts are not resulting from a slightly older treatment group. Compared to the baseline results, the effect is larger. It could be the case that some mental illness has not been diagnosed yet among the younger cohorts; thus, the effect of a typhoon is not as pronounced. As mentioned in section 2, there were a few severe typhoons that did not make landfall. In baseline specification, individuals who were in utero during these non-landfall typhoons are being recorded as exposed to severe typhoon in non-landfall region. In column 4, we estimate the effect excluding those individuals. The estimation results remain comparable to the baseline.

We have discussed the downside of using the insurance claim dataset–we do not know one's birth location. We try to minimize migration issues in the baseline by restricting to people who live in rural areas. To further reduce the migration issue, we restrict the sample to those residing in areas with little in-migration. We use the 2000 census to calculate in-migration rates based on the share of current residents that were born in the same county. We restrict our empirical analysis to those *counties* where in-migration rate is less than 20%. This reduces our sample size by more than half. The regression results are shown in Column 5. Column 6 of Table 6 includes region-by-year fixed effects to further control region-specific cohort differences in mental health outcomes. The results are consistent with the main results.

Lastly, as a placebo test and to address concerns over statistical inference in small number of clusters, we implement permutations tests. In the permutation test, the timing of severe typhoons and landfall counties are randomly drawn without replacement. For each permutation, the timing and landfall location of severe typhoons are randomly chosen. Individuals' prenatal exposures are then assigned accordingly.[16] We then estimate the effects of severe typhoons based on placebo exposure status. Figure 4 displays the

[16]Permutation tests have been used recently in the following papers: Agarwal et al. (2015), Bloom et al. (2013), and Chetty et al. (2011).

empirical distributions of the placebo treatment effects on outpatient psychiatric-related visits from 1,000 permutation tests. The fact that the distribution is centered at zero is comforting as these placebo tests are expected to find no impacts. When we compare the treatment effects that are based on actual exposure, the results indicate that less than 1% of the time permutation estimates are larger than the estimates of actual treatment. This result, based on permutation tests, reassures us that the effect of a severe typhoon is statistically significant.

5 Discussion and Conclusion

There is a vast literature examining the long-term impact of *in utero* exposure to poor intrauterine environment. Many of the papers examine education, general health outcomes, and labor market outcomes. This paper extend our knowledge about the impact of poor prenatal environment on mental health. We find that the likelihood of mental illness increases by 12% for individuals who had *in utero* exposure to severe typhoons in landfall counties as compared to their unexposed peers. These individuals also tend to have more psychiatric-related health care utilization. Compared to the effects of exposure in the first few years of life, we find that *in utero* exposure has the greatest impacts on mental health. The negative effects on mental health are much larger for women than for men.

In a regression not shown here, we also examine various physical health outcomes. Papers by Mazumder et al. (2010) and Lin and Liu (2014) find that poor prenatal environment causes cardiovascular/circulatory problems later in life. Given the health claim data available, we also look at the cardiovascular/circulatory problem. However, among the age group we examine (between age 28 and 43), the incidence of heart diseases and hypertension is extremely low. We find a small positive insignificant result, probably due to the lack of statistical power.

There are many possible reasons why in utero exposure to a severe typhoon can cause poor outcomes. A severe typhoon can lead to worse sanitation environment, lack of access to health care, household income shocks, worse parental health, maternal stress, and disruption of nutritional intake. Although due to data limitation, we cannot further explore the specific channels, but it should be of interest for future research. Often time immediately after a natural disaster, the attention is focused on the massive economic disruption. Our finding suggests that there could be additional consequences that are not immediately noticeable. Given the tremendous costs that are associated with mental disorders, welfare could be drastically improved by providing timely assistance to affected pregnant women.

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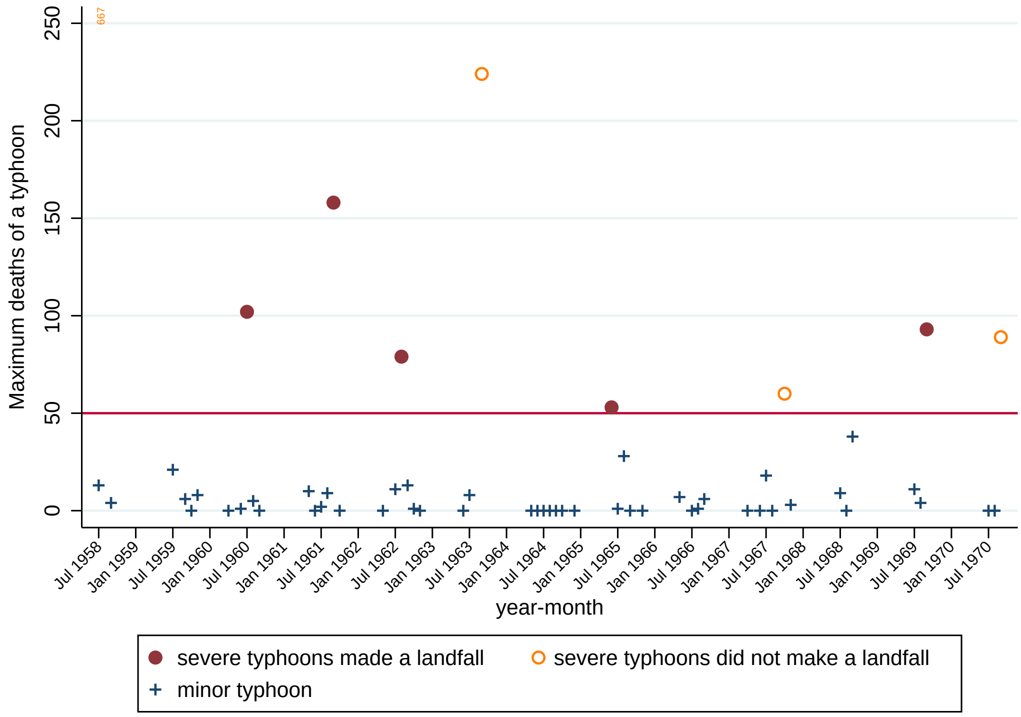
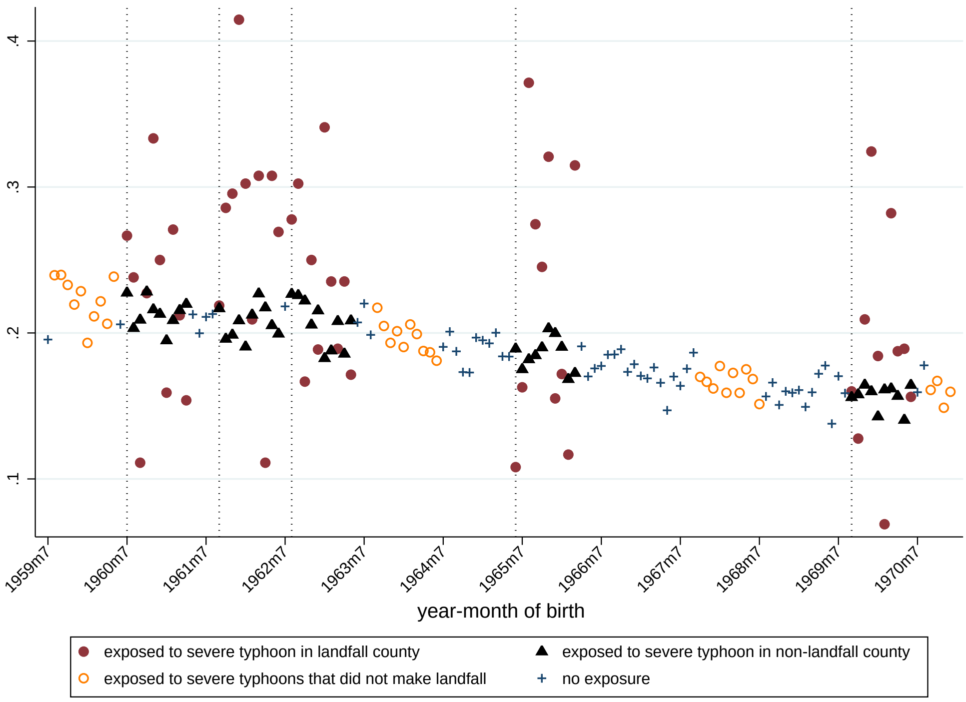
Figure 1: Death Tolls from Typhoons by Year-Month, 1958-1970



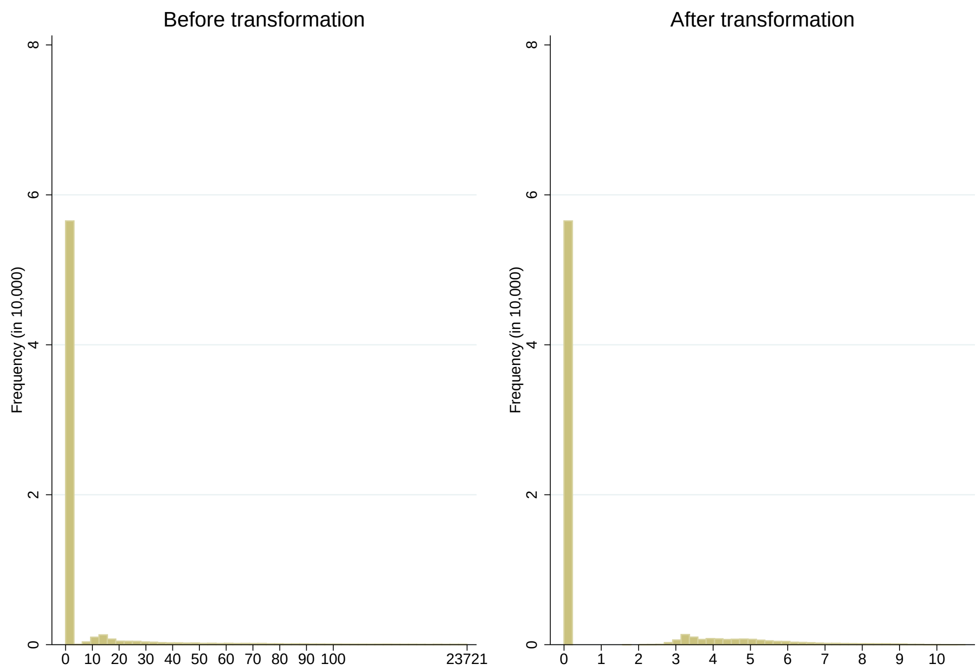
Notes: Data Source: The Typhoon Database of the Central Weather Bureau and the 2013 Annual Disaster Report from the National Fire Agency. Each point represents the number of deaths caused by a given typhoon at the national level. Solid circles indicate typhoons that made landfall and caused more than 50 deaths. Hollow circles show the typhoons that did not make landfall and caused more than 50 deaths. Pluses refer to the typhoons that caused fewer than 50 deaths. When there are multiple typhoons in a given year-month, only the typhoon that caused the most deaths is presented in this figure. In the main analysis, a severe typhoon is defined as one causing more than 50 deaths. Y-axis represents the deaths toll for a given typhoon. X-axis indicates year and month.

Figure 2: The Likelihood of Mental Illness by Intrauterine Exposure to Severe Typhoon



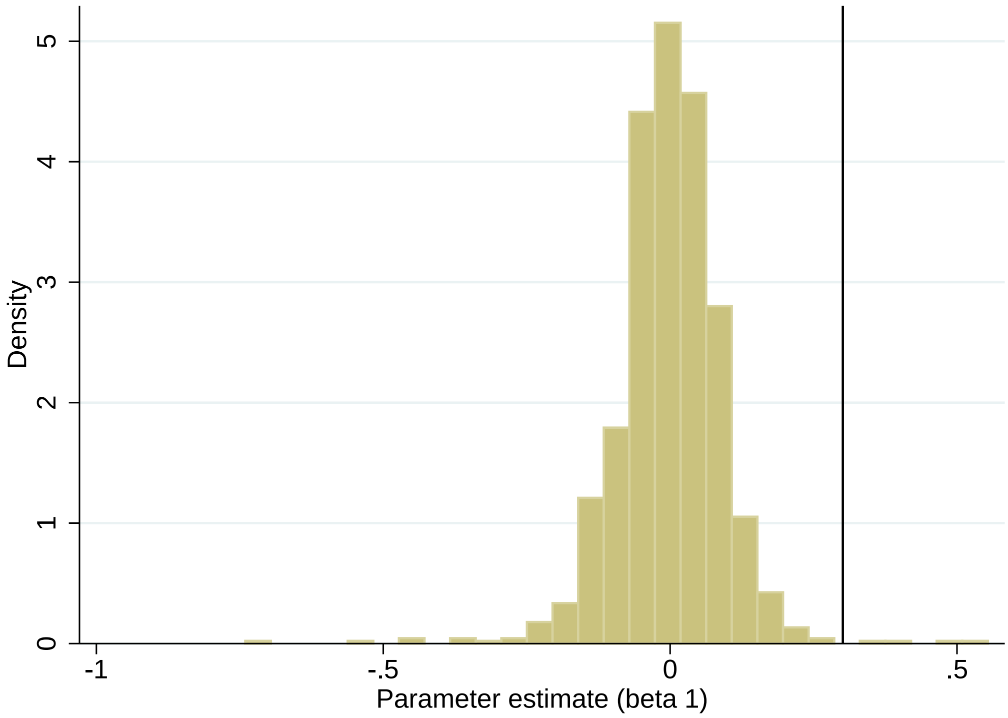
Notes: Data source: 5% Health Insurance Claim Records, 1998-2002. Mental illness is measured as ever been diagnosed with mental disorders based on ICD-9 codes (physician diagnosis). Likelihood of mental illness is aggregated to year-month of birth and *in utero* exposure to severe typhoons status. Severe typhoon is defined as a typhoon that caused 50 deaths. Each point represents a given birth cohort (at the year-month level) and its exposure to severe typhoon. The dotted lines show when severe typhoons made landfall. Solid circles refer to the cohorts that had fetal exposure to severe typhoons in landfall county. Triangles show the cohorts that had fetal exposure to severe typhoons in non-landfall county. Hollow circles indicate the cohorts that had fetal exposure to severe typhoons that did not make landfall. Pluses show the cohorts that had no fetal exposure to severe typhoons. Y-axis represents the share of mental illness for a given birth cohort. X-axis indicates year-month of birth.

Figure 3: Histograms of Psychiatric-Related Outpatient Health Care Expenditures (in 2011 USD)



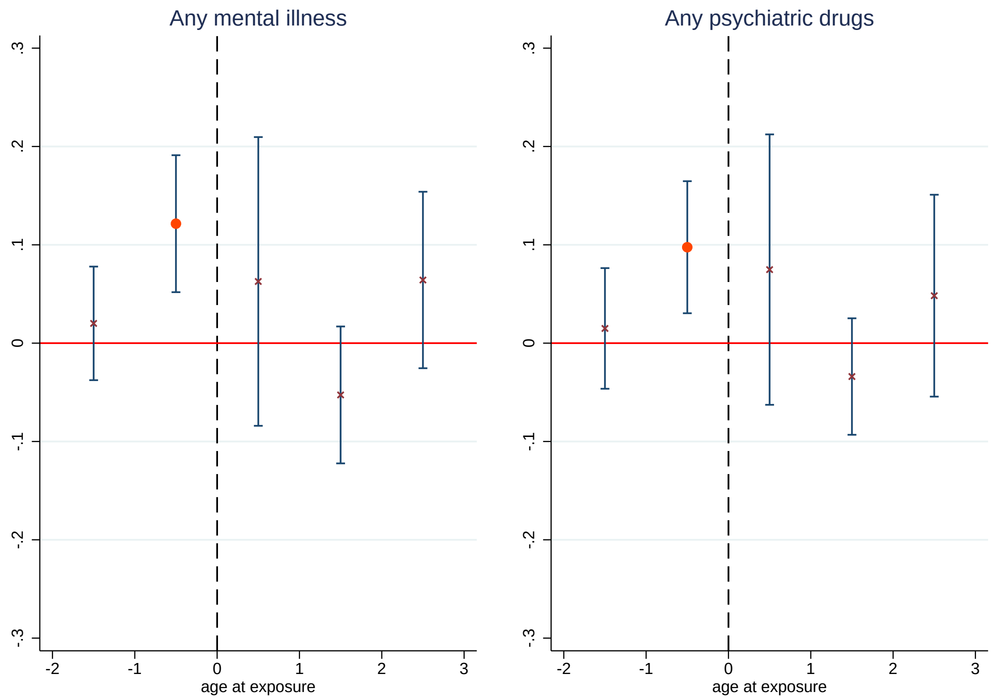
Notes: Data source: 5% Health Insurance Claim Records, 1998-2002. The histograms on the left and right display, respectively, psychiatric-related expenditures before and after applying inverse hyperbolic sine transformation method ($log(y + (y^2 + 1)^{0.5})$). Expenditures are inflation-adjusted and in 2011 USD. Y-axis represents the frequency of a given amount of expenditures. X-axis indicates total psychiatric-related outpatient expenditures over the five years.

Figure 4: Permutation Test Result for Outpatient Psychiatric-Related Visits
Coefficient of (Exposed)*(Landfall County), β_1



Notes: We assigned placebo treatment (prenatal exposure to severe typhoons) in randomly selected year-month and county drawn without replacement. The histogram displays the coefficient estimates of an interaction term between *in utero* exposure to severe typhoon and landfall county from 1,000 permutations. The vertical line shows the estimates of the actual prenatal exposure. Exposure to severe typhoons is a dummy variable, which equals 1 if one was *in utero* during a severe typhoon. Severe typhoon is defined as a typhoon that caused 50 deaths. Landfall county equals to 1 if one resides in the landfall county for the given typhoon. Omitted group is individuals who were not exposed to a severe typhoon while *in utero*. The results show that 4 out of 1,000 permutation estimates are greater than that of actual treatment.

Figure 5: Impacts of Exposure to Severe Typhoon by Birth Cohort
Coefficient of (Exposed)*(Landfall County), β_{1x}



Notes: Sample comprises female individuals who were born between 1964 and 1970. Regression estimates of Equation 3 from linear probability models are plotted. The dots, crosses, and bars correspond to the coefficient estimates with 95% confidence intervals. The estimate illustrates the difference in outcome variables between those individuals who were exposed to severe typhoons at age x relative to individuals who were not exposed to severe typhoons at age x. The dot represents the differences in outcomes between individuals who were exposed to severe typhoons and individuals who were not exposed to severe typhoons within one year before birth, which covers the *in utero* period. Omitted group is individuals who did not have severe typhoon exposure between two years before and three years after birth. The covariates include year of birth fixed effects, month of birth fixed effects, county fixed effects, county-specific cohort trends, and a set of interaction terms between non-landfall county and exposure at age x to severe typhoon (see Equation 3). Exposure to severe typhoons is a dummy variable, which equals 1 if one was at age x during a severe typhoon. Severe typhoon is defined as a typhoon that caused 50 deaths or more. Landfall county equals 1 if one resides in the landfall county for the given typhoon. X-axis measures age at exposure.

Table 1: Descriptive Statistics, Health Insurance Claim Records 1998-2002

	All	W/ in-utero exposure		W/o in utero exposure	P-value of H0: (2)=(4)	P-value of H0: (3)=(4)
		Landfall county	Non-landfall county			
	(1)	(2)	(3)	(4)	(5)	(6)
Individual characteristics						
Age	37.5	38.0	38.0	37.1	0.00	0.00
	(3.42)	(3.17)	(3.55)	(3.23)		
Male	0.50	0.51	0.50	0.50	0.63	0.02
	(0.50)	(0.50)	(0.50)	(0.50)		
Health Outcomes						
Ever had any mental disorders	0.20	0.25	0.21	0.20	0.00	0.00
	(0.40)	(0.43)	(0.41)	(0.40)		
Ever been prescribed psychiatric drugs	0.16	0.21	0.17	0.16	0.00	0.00
	(0.37)	(0.40)	(0.38)	(0.36)		
Ever been hospitalized in psychiatry	0.007	0.016	0.006	0.007	0.02	0.09
	(0.082)	(0.13)	(0.078)	(0.084)		
Number of psychiatric-related outpatient visits	1.58	2.66	1.56	1.58	0.00	0.77
	(8.29)	(11.6)	(7.64)	(8.78)		
Total psychiatric-related outpatient expenditures	61.3	115.9	58.8	62.1	0.01	0.35
	(460.1)	(679.5)	(431.7)	(478.5)		
N	69,549	1,056	34,047	34,446		

Notes: Data source: 5% Health Insurance Claim Records, 1998–2002. Unit of observation is individual. Analytical sample includes individuals who were born between 1959 and 1970 and currently reside in rural townships (s*hiang*). Individual characteristics are observed in 2002, and health outcomes are aggregated across 1998-2002 based on claim records. Standard deviations are reported in parentheses.

Table 2: Impact of Intrauterine Exposure to Severe Typhoon on Mental Health

	Panel A: Ever been diagnosed with:			
	Any mental disorders	Anxiety and personality disorders	Mood disorders	Schizophrenia
	(1)	(2)	(3)	(4)
(exposed to severe typhoon)	0.024***	0.019**	0.017***	0.004***
*(landfall county), β1	(0.009)	(0.008)	(0.006)	(0.001)
(exposed to severe typhoon)	0.005	0.005*	0.004**	-0.001*
*(non-landfall county), β2	(0.004)	(0.003)	(0.002)	(0.001)
Mean (Dependent variable)	0.200	0.150	0.040	0.010
P-value of H0: β1=β2	0.030	0.069	0.026	0.001
	Panel B: Ever been prescribed:			
	Any psychiatric drugs	Antidepressants	Anxiolytics	Antipsychotics
(exposed to severe typhoon)	0.018*	0.026***	0.013	0.004
*(landfall county), β1	(0.010)	(0.009)	(0.011)	(0.008)
(exposed to severe typhoon)	0.008**	0.004**	0.006*	-0.002
*(non-landfall county), β2	(0.004)	(0.002)	(0.004)	(0.001)
Mean (Dependent variable)	0.160	0.050	0.150	0.040
P-value of H0: β1=β2	0.348	0.020	0.597	0.423

Notes: Sample is as described in Table 1. N=69,549. This table presents the results of estimating specification (1) from linear probability models. Models also control for an indicator for male, year of birth FE, month of birth FE, county FE, and county-specific cohort trends. Exposure to severe typhoons is a dummy variable, which equals 1 if one was in utero during a severe typhoon. Severe typhoon is defined as a typhoon that caused 50 deaths. Landfall county equals 1 if one resides in the landfall county for the given typhoon. Non-landfall county is a dummy variable indicating whether individual resides in the non-landfall county for a given typhoon. Omitted group is individuals who were not exposed to severe typhoons while in utero. Standard errors are clustered at the county level. *** p<0.01, ** p<0.05, * p<0.1

Table 3: Impact of Intrauterine Exposure to Severe Typhoon on Psychiatric-Related Health Care Utilization

	Number of Psychiatric-Related Visits		Total Outpatient Psychiatric-Related Expenditure		Out of Pocket Psychiatric-Related Expenditure	
	Poisson	Negative Binomial	Inverse hyperbolic sine transformation	Log (y+1) transformation	Inverse hyperbolic sine transformation	Log (y+1) transformation
	(1)	(2)	(3)	(4)	(5)	(6)
(exposed to severe typhoon)	0.301***	0.303**	0.123***	0.109***	0.077**	0.068**
*(landfall county), β1	(0.101)	(0.128)	(0.040)	(0.034)	(0.034)	(0.030)
(exposed to severe typhoon)	-0.059	-0.059	0.023	0.020	0.017	0.014
*(non-landfall county), β2	(0.045)	(0.044)	(0.016)	(0.014)	(0.011)	(0.010)
Mean (Dependent variable)	1.58	1.58	61.3	61.3	4.9	4.9

Notes: Sample is as described in Table 1. N=69,549. Column 1 use Poisson specification, column 2 uses negative binomial FE models, columns 3 to 6 use ordinary least square model. Expenditures are inflation-adjusted and in 2011 USD. Columns 3 and 5 apply inverse hyperbolic sine transformation to dependent variables ($\log(y+(y^2+1)^{0.5})$). Columns 4 and 6 apply conventional log transformation to dependent variables ($\log(y+1)$). We also control for an indicator for male, year of birth FE and month of birth FE, county FE, and county-specific cohort trends. Exposure to severe typhoons is a dummy variable, which equals 1 if one was in utero during a severe typhoon. Severe typhoon is defined as a typhoon that caused 50 or more deaths. Landfall county equals 1 if one resides in the landfall county for the given typhoon. Non-landfall county is a dummy variable indicating whether individual resides in the non-landfall county for a given typhoon. Omitted group is individuals who were not exposed to severe typhoons while in utero. Standard errors are clustered at the county level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 4: Impact of Intrauterine Exposure to Severe Typhoon on Mental Illness by Gender

	Male		Female	
	Mean	Coefficient for (exposed)* (landfall), β1	Mean	Coefficient for (exposed)* (landfall), β1
Dependent Variable:	(1)	(2)	(3)	(4)
Ever been diagnosed with any mental disorders	0.162	-0.012	0.247	0.063***
		(0.019)		(0.014)
Ever been prescribed any psychiatric drugs	0.127	-0.004	0.201	0.040***
		(0.016)		(0.008)
Number of psychiatric visits	1.481	0.251	1.685	0.364***
		(0.288)		(0.086)
Psychiatric-related outpatient expenditures	62.71	-0.059	59.82	0.332***
		(0.098)		(0.082)
N		34,811		34,738

Notes: Sample is as described in Table 1. Expenditures are inflation-adjusted, and in 2011 USD. Inverse hyperbolic sine stransformation is applied to psychiatric-related outpatient expenditures. Models also control for year of birth FE, month of birth FE, county FE, county-specific cohort trends, and a set of interaction terms between non-landfall county and in utero exposure to severe typhoon (same as Table 2). Exposure to severe typhoons is a dummy variable, which equals 1 if one was in utero during a severe typhoon. Severe typhoon is defined as a typhoon that caused 50 or more deaths. Landfall county equals 1 if one resides in the landfall county for the given typhoon. Omitted group is individuals who were not exposed to severe typhoons while in utero. Standard errors are clustered at the county level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 5: Robustness Checks with Alternative Definition of Severe Typhoons

	Dependent Variable: Ever been diagnosed with any mental disorders, female only				
	Basline Specification	Deaths≥20	Deaths≥70	Collapsed buildings≥2000	Collapsed buildings≥4000
	(1)	(2)	(3)	(4)	(5)
(exposed to severe typhoon)	0.063***	0.043**	0.046***	0.052***	0.059***
*(landfall county), β1	(0.014)	(0.019)	(0.011)	(0.017)	(0.017)
(exposed to severe typhoon)	0.004	0.005	0.000	0.003	0.003
*(non-landfall county), β2	(0.005)	(0.005)	(0.009)	(0.005)	(0.005)
Number of severe typhoons	5	7	4	8	7

Notes: Sample is as described in Table 1, but female only. N=34738. This table presents the estimation restults from linear probability models. Dependent Variable is ever been diagnosed with any mental disorders. Models also control for year of birth FE, month of birth FE, county FE, and county-specific cohort trends. Exposure to severe typhoons is a dummy variable, which equals 1 if one was in utero during a severe typhoon. Baseline definition of severe typhoon indicates a typhoon that caused 50 or more deaths. This table use alternative measures including 20 and 70 deaths, and 2,000 and 4,000 collapsed buildings. Landfall county equals 1 if one resides in the landfall county for the given typhoon. Non-landfall county is a dummy variable indicating whether individual resides in the non-landfall county for a given typhoon. Omitted group is individuals who were not exposed to severe typhoons while in utero. Standard errors are clustered at the the county level. *** p<0.01, ** p<0.05, * p<0.1

Table 6: Robustness Checks with Subsamples and Additional Controls

	Dependent Variable: Ever been diagnosed with any mental disorders					
	Baseline specification	Excluding north and central regions	Excluding year of birth>=1966	Excluding cohorts exposed to no-landfall severe typhoons	Excluding counties with migration rate>=20%	Including region-year of birth FE
	(1)	(2)	(3)	(4)	(5)	(6)
(exposed to severe typhoon)	0.063***	0.061***	0.105***	0.062***	0.050**	0.061***
*(landfall county), β1	(0.014)	(0.019)	(0.033)	(0.017)	(0.023)	(0.020)
(exposed to severe typhoon)	0.004	-0.007	0.001	0.008	0.011	0.004
*(non-landfall county), β2	(0.005)	(0.008)	(0.006)	(0.007)	(0.011)	(0.005)
N	34,738	13,711	20,513	26,362	11,620	34,738

Notes: All regression are restricted to female only. Columns 1 to Column 6 of this table present the estimation results from linear probability models. All models also control for year of birth FE, month of birth FE, county FE, and county-specific cohort trends. Columns 1–6 cluster standard errors at the county level. Exposure to severe typhoons is a dummy variable, which equals 1 if one was in utero during a severe typhoon. Severe typhoon is defined as a typhoon that caused 50 or more deaths. Landfall county equals 1 if one resides in the landfall county for the given typhoon. Non-landfall county is a dummy variable indicating whether individual resides in the non-landfall county for a given typhoon. Omitted group is individuals who were not exposed to severe typhoons while in utero. Standard errors are shown in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

A Appendix

A.1 ICD-9 Diagnosis Codes

Any mental disorder: 290.xx-312.xx

Anxiety and personality disorders: 300.xx, 301.xx

Mood disorders: 296.xx, 300.4x, 311.xx

Schizophrenia: 295.xx

Illnesses classified as anxiety disorders: generalized anxiety disorder, panic disorder, Obsessive-compulsive disorder (OCD), PTSD, and phobias

Illnesses classified as personality disorder: paranoid personality disorder, schizoid personality disorder, schizotypal personality disorder, antisocial personality disorder, borderline personality disorder, histrionic personality disorder, narcissistic personality disorder, avoidant personality disorder, dependent personality disorder, obsessive-compulsive personality disorder.

Illnesses classified as mood disorder: depression, bipolar disorder

Prior to 2000, most physicians and clinics/hospitals used A-codes before 1999. Starting from 2000, classifications were switched to ICD-9 codes. We converted the relevant A-codes to ICD9 codes for the analysis. For most part, we follow the same categorization as Reeves et al. (2011). However, A-code does not distinguish anxiety and personality disorder, so we cannot separately analyze these two categories.

A.2 ATC Codes

Antidepressants: N06A, N06CA

Anxiolytics: N05B

Antipsychotic: N05A