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The Long-Term Effect of Earthquakes on Birth Outcomes: Evidence from the 2008 Sichuan Earthquake

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An abstract of
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Abstract

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This paper investigates the effect of the 2008 Sichuan Earthquake on the birth outcomes of the region. I hypothesize that the event leads to a decrease in birth weight as well as a continuous but declining negative effect in the years after. Using a difference-in-difference framework, I find evidence supporting the earthquake lowering the birth weights of the region from the years 2008-2014, but am not able to show a decline in magnitude throughout the period. I outline two possible explanations of unknown exogenous effects as well as the incompatibility of the parallel assumption.

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1 Introduction

The effects of natural disasters on the short-term and long-term health of a community is an important question as it can inform about the true cost to an extreme event. Events such as earthquakes can lead to long-lasting effects that go beyond the initial casualties. Through mechanisms such as disaster-induced stress, economic strain, and long-term stress, the health of the region can be distorted beyond the actual impact of a large earthquake. This is an important problem for economists as not only are there well-established linkages between various health factors and financial outcomes (Hodek et al., 2011; Black et al., 2007; Grimard and Lazslo, 2014; Almond et al., 2005), but understanding the long-term health costs have policy implications for post-event recovery efforts.

As I will describe later further in detail, natural disasters can have widespread negative effects on health due to not only the initial damage, but also the prevalence of stress and other mental health related factors. Studies such as Başoğlu (2005) show that prevalency of

PTSD and earthquakes are seen years following a large natural disaster. Due to many papers linking these stress events to health variables such as birth weight (Wadhwa et al. 1993), this can have wide implications on the full recovery of the community. As these stressors can persist even after initial damages from the event are remedied, this can result in damages that are not accounted for during recovery plans.

Earthquakes can also be exploited for research purposes due to their unexpected, yet highly destructive nature. Due to this randomness, individuals are selected independent of specific characteristics, meaning it is possible to gain insight into the difference between the treated and untreated groups. These natural experiments can thus be used to find causality where it would not have been clear before.

In this paper, I seek to uncover the magnitude and length of the effect that earthquakes have on infant health. My hypothesis is that 1) The 2008 Sichuan Earthquake induces lower birth weights in the region that can be seen years after the event. 2) This induction in lower birth weights has a ripple effect where the effect of birth weight being lowered are diminished through the years following the event.

I exploit the 2008 Sichuan Earthquake as a natural experiment and examine the birth records of Chinese infants that were exposed to the earthquake. Additionally, I aim to uncover the persistence and shock of this exogenous effect on the infant health of the region by examining the effects of the event years after. This is to determine whether there is a ripple effect of the earthquake throughout the region affected and the duration and magnitude of said effect.

I use the 2008 Sichuan earthquake as an event study as many of the literature dealing with exogenous disaster shocks on health are mostly done on developing nations (Koppensteiner and Manacorda, 2016; Currie and Rossin-Slater, 2013; Torche 2011). China offers an interesting perspective of a country that pooled together its resources as a developed nation to help with post-disaster relief. Additionally, many of the studies conducted in developed nations focus on multiple randomized small disasters that may not lead to as much psychological stress as a large devastating event. By using this large earthquake, it will be able to show the long-term effects of disasters on the health of a developed society. Additionally, I broadly contribute to the literature by presenting the long-term effect of natural disasters on the birth outcomes of a region. Many of the existing literature only focuses on proving causality between short intervals following the event, not tracking the lingering stressors created by the earthquake.

I utilize the China Family Panel Studies (CFPS), a nationally representative biennial longitudinal survey provided by the Institute of Social Science Survey (ISSS) of Peking University, China. I combine the datasets from the years of 2010, 2012, 2014, 2016, and 2018 in order to analyze the health of the society throughout a spectrum of time. My sample thus includes individuals born from 2004 to 2017. My empirical strategy exploits the province-specific 2008 Sichuan earthquake and uses a difference-in-differences (DD) framework to compare children born in the affected province to those born outside of it.

I find that children born in the period between 2008-2014 in Sichuan experience a loss of 150 grams and increases the probability of being born with a birth weight below 2.5 kilograms by 7.4 percentage points. I also find that individually, each individual year cohort exposed to the earthquake experiences substantial losses of birth weight significant at the 5% significance level in the years 2008, 2010, 2011, 2013, and 2014. Similar results are seen when looking at the the probability of lowbirth of each year's cohort. I fail to observe a consistent diminishing effect of lowered birth weights following the event. I propose a few explanations for this including the possibility of an outside shock affecting birth weights in that period as well as the violation of the parallel assumption used in the difference-in-difference (DD) estimation.

The rest of the paper will precede as follows: Section 2 provides a review of the prevailing literature and context behind 2008 Sichuan Earthquake, stress mechanisms, and shocks to birth outcomes. Section 3 describes the data source as well as the different variables and instruments used to conduct the study. Section 4 looks at the methodology used to conduct the analysis. Section 5 describes the results of the study while Section 6 has the conclusion detailing limitations and further questions. Finally, Section 7 contains all the tables and figures followed by all my references in Section 8.

2 Literature Review and Background

2.1 Literature on prenatal shocks on health

The premise of stressful events being examined to look at birth outcomes yields several results in the current literature. Brown (2011) uses terrorist attacks as a stress mechanism to observe birth weight differences. Using the 9/11 terrorist attack and holding other externalities constant such as pollution and resource shocks, the study looks at the timing of the attack on different months that a mother was pregnant. The results also show that those witnessing the stressful event during their first trimester saw a decrease in birth weight while those witnessing it during mid-pregnancy saw a notable decrease in gestational age.

Mansour (2011) employed the effects of fatalities caused by Israeli security forces and the birth weight as a natural experiment. To reduce confounding variables, the study looked at siblings who were in utero during different levels of fatalities. What was found was that fatalities occurring in the first trimester of pregnancy are positively related to the probability that a child weighs less than 2500 grams at birth. Another paper, Koppensteiner (2016), used local homicide rates of Brazilian municipalities as an exogenous shock. What he found were similar results where exposure to violence resulted in small, but precise increases in risks of low birth weights and prematurity. This effect was seen in both municipalities with low homicide rates and those that had large homicide rates. It also found that the children born to poorly educated mothers saw the most drastic drop in healthy birth outcomes leading to concerns of compounded inequality.

Factors such as nutitional shocks are also taken into account. Hoynes, Page and Stevens (2009) looked at the introduction of a U.S. government program called WIC (Women Infants and Children) which increased the nutritional intake of low-income pregnant women. By taking advantage of the nonuniform roll-outs between different counties in the United States, the study found that implementation of WIC lead to an increase in average birth weight and a decrease in the fraction of births that are classified as low birth weight.

There is also a plethora of literature on natural disasters being used as instruments to measure stress effects on birth outcomes. One of the first landmark studies that looked at how natural disasters affected pregnant women was Glynn et al. (2001) which looked at the effects of a 1994 earthquake in Northridge, California on 40 women who were pregnant or postpartum at the time of the event. What the authors found is that this exposure to the earthquake was correlated with a shorter gestation period. Additionally, similar to studies discussed before, it found significant effects with women experiencing earthquakes earlier in their pregnancy. Later on, research such as Currie and Rossin-Slater (2013) looked at hurricanes occurring throughout Texas as a mechanism for stress and found that these exposures heightened the probability of abnormal conditions to occur to the newborn such as being on a ventilator more than 30 minutes and meconium aspiration syndrome (MAS).

2.2 Mechanism of stress

There are two main mechanisms that are used to explain the influence of natural disasters on fetal health: a biological basis of maternal stress being passed down to the fetus and disasters inducing negative economical and infrastructural damages leading to lower birth weights. The former hypothesises that there is a biological channel where acute stress is passed from mother to child. The medical literature indicates that this channel is due to prenatal stress raising the levels of Corticotrophin-Releasing Hormone (CRH) which regulates the duration of pregnancy and fetal maturation (Wadhwa et al. 1993). Multiple economic studies have attempted to isolate this effect. Camacho (2008) examines landmine explosions caused by terrorist attacks in Colombia, controlling for specific regions in Colombia and also maternal-effects by looking at siblings. What the study found was significant correlation in low birth weight given stress induced by the terrorist attacks that occurred earlier in the pregnancy. This study then argues that this is evidence of the stress hormone hypothesis. This is because birth outcomes has been shown to be most sensitive to maternal stress in early stages of pregnancies (Glynn et al., 2001) which means evidence significantly linking the exposure period of the first trimester to low birth outcomes would support this explanation. This is similarly observed in other economic studies linking lower birth outcomes and stressful events (Le and Nguyen, 2020, Torche, 2011, Quintana-Domeque, Rodenas-Serrano, 2017).

Additionally, earthquakes have disruptive effects on infrastructure and economic channels that promote prenatal health. Negative health infrastructural shocks are common with earthquakes with healthcare centers often becoming damaged (Shahpari et al. 2021). Alongside this destruction, economic pathways are affected with GDP being negatively impacting and persisting in the long term post-event (Barone and Mocetti 2014). This degradation of proper economic and health systems can lead to pregnant mothers not receiving the proper care that they would have if not for the earthquake.

2.3 Background on the 2008 Sichuan Earthquake

The 2008 Sichuan Earthquake was a 7.9 magnitude earthquake that occurred in the mountainous central region of Sichuan province in southwestern China on May 12, 2008. This earthquake was caused by the collision of the Indian-Australian and Eurasian plates across the Longmenshan fault. Around 90,000 people were counted as dead or missing and presumed dead while 375,000 people were injured by falling debris and collapsed buildings. This event left millions homeless with the cost estimated at 845 billion RMB (122 billion USD). At the end of it, the government declared 10 counties severly destroyed and 29 counties heavily affected (The Guardian, 2008).

This earthquake proved to be among the deadliest in Chinese history. Aid was established shortly after with many international organizations and government interventions coming together to fix the situation in southwest China. Initiatives were propped up with resources being pooled into the region including a three-year target in which all damaged households would have their houses rebuilt. Alongside these recovery efforts, international and domestic efforts were made to establish counseling and mental health efforts. Witnesses to the destruction and death lead to many developing stress-linked symptoms such as PTSD and depression. However, the effectiveness of these mental health initiatives have found to be mixed and in some cases ineffective (Ren et al. 2016).

Studies have detailed the prevalence of stress in the region affected by the earthquake. One study demonstrated that it was common for adults exposed to the earthquake to have experienced posttraumatic stress disorder (PTSD) three months after the event (Wang et al. 2009). Another study found that children surveyed a year after the earthquake was prone to develop PTSD, depression, and anxiety (Liu et al. 2011) These symptoms were heavily linked with initial exposure to death, bereavement, and extreme fear arising from the event. From this it can be seen that even months and years after the event, the stress levels of a society are impacted beyond the initial exposure. This can possibly lead to worsening physical symptoms linked with stress and result in a declining health ripple effect.

3 Data Description

The dataset I employ is the Chinese Family Panel Studies (CFPS) which is a nationally representative, annual longitudinal survey of Chinese communities, families, and individuals launched in 2010 by the Institute of Social Science Survey (ISSS) of Peking University, China. This contains community-wide variables such as demographic information, health, and identifying variables. These surveys are published biannually from 2010 to 2018. The target sample consists of 16,000 households in 25 provinces in China. Those who are eligible to be surveyed are those who live in a residential community with one or more family members of Chinese nationality. The survey is split into child, adult, family, and community surveys. For this study I employ the child survey which contains data on every individual up to the age of 16. I construct the final dataset by combining the 2010, 2012, 2014, 2016, and 2018 datasets, controlling for specific individuals via the Personal ID variable that stays constant for the same person throughout the different surveys.

I use variables that identify the child's birth year, birth month, province, birth weight, and gender to define my exposure and treatment groups. The summary statistics are shown in Table 1 and Table 2.

4 Methodology

I seek to find causation in the effect of the Sichuan earthquake in disrupting the long-term birth outcomes of the region by focusing on two main models. Both of these employ a difference-in-differences (DD) approach to look at the period of time in which the treatment was significant. I define my base year as 2007, the year right before the earthquake struck, and use this as my initial difference.

I first look at each year following the earthquake and observe each year's deviation from the base year by utilizing a dynamic difference-in-difference model. I use these two equations to model this:

(1)

$$BWT_{c,p,t} = \beta_0 + \sum_{i}^{j} \beta_t \times (sichuan_{c,t} \times byear_{c,p}) + \chi_{c,p,t} + \lambda_c + \gamma_t + \epsilon_{c,p,t}$$

(2)

$$LBWT_{c,p,t} = \beta_0 + \sum_{i}^{j} \beta_t \times (sichuan_{c,t} \times byear_{c,p}) + \chi_{c,p,t} + \lambda_c + \gamma_t + \epsilon_{c,p,t}$$

where c = child, p = province, and t = birth year.

Equation (1) uses birth weight as an explanatory variable where birth weight is measured in kilograms. Alternatively, equation (2) employs low birth weight as the dependent variable, defined as a dummy variable indicating whether birth weight is lower than 2.5 kilograms. χ represents a matrix of child specific covariates including the gender, province, and whether the region the child lived in was urban. λ represents province specific fixed effects. γ represents the birth year fixed effects. ϵ is the idiosyncratic error term. The interaction term $sichuan \times byear$ is the variable of interest with the variable *sichuan* equalling one if the individual is in the province of Sichuan and zero if not and *byear* being the year that the child was born. In equation (1) and (2), I use a dynamic model in which I can look at the differences within the treated and nontreated group in 2007, the year right before the earthquake, and compare them to the treated and nontreated group from the years following the event. This allows me to attain a fuller picture of the scale and longevity that the earthquake had on birth outcomes. Thus, β_t captures the effect of the exposure to the earthquake at year t compared to the pre-earthquake base year of 2007.

I then look to see if as a whole those born within the years of 2008-2014 had significant changes in birth weights. I model this by the equations:

(3)

$$BWT_{c,p,t} = \beta_0 + \beta_1 \times (sichuan_{c,t} \times period_{c,p}) + \chi_{c,p,t} + \lambda_c + \gamma_t + \epsilon_{c,p,t}$$

(4)

$$LBWT_{c,p,t} = \beta_0 + \beta_1 \times (sichuan_{c,t} \times period_{c,p}) + \chi_{c,p,t} + \lambda_c + \gamma_t + \epsilon_{c,p,t}$$

where c = child, p = province, and t = birth year. The dependent variable of BWT and $LBWT$ remain the same with the only change being the replacement of the explanatory variables with $sichuan \times period$ which is used to model the effect of those born in the region of Sichuan during the treatment period from 2008-2014. χ represents a matrix of child specific covariates including the gender, province, and whether the region the child lived in was urban. λ represents province specific fixed effects. γ represents the birth year fixed effects. ε is the idiosyncratic error term.

5 Results

Table 4 presents the results for equation (1) and equation (2) with each column presenting the different regressions. Equation (1) uses BWT as a dependent variable with the explanatory variables being the different interaction terms from 2004-2017 using 2007 as a base year. Equation (2) alternatively uses LBWT as the dependent variable. Table 5 displays the regression results for equation (3) and equation (4). These models are similar to the ones used in the previous table but instead of measuring the interaction between all years and the base period 2007, it uses the interaction variable of $sichuan \times period$ to look at the effect of birth outcomes in those born in Sichuan between 2008-2014. Both models have province, individual, and time fixed effects included as well as covariates of gender, province, and urban environment. Additionally, all models have standard errors clustered on the provincial level.

Model 1 shows that every year from 2008-2014 besides 2009 and 2012 showing a negative relationship between the treatment and the resulting birth weight at a 1% significance level. $sichuan \times 2009$ shows a positive increase of .0681 at a 5% significance level while $sichuan \times 2012$ implies a decrease in 93.8 grams at the 5% significance level. After 2014, the values lose statistical significance with $sichuan \times 2015$ being the last statistically significant value at the 10% level. Figure 3 illustrates the coefficient values and its overall negative effects throughout the period of interest. These interaction terms appear to support my hypothesises as not only do they show the treatment inducing a negative effect on birth weights, but additionally the most significant coefficients are obtained from the 2008-2014 period. Model 2 yields similar results that seem to support my overall hypothesis with the examined period displaying significant increases in low birth weights (defined as less than 2.5 kilograms). The only birth weight cohort that does not indicate an increase in low birth weights is 2012. Figure 4 illustrates the coefficient plot of Model 2.

Table 5 demonstrates whether those born in the period of 2008-2014 in Sichuan have a significant decrease in weight. What it demonstrated was there is a 150 gram decrease to birth weight significant at the 1% significance level. Additionally, the propagation of low birth rates increased by 7% in that period also at the 1% confidence level.

These findings reinforce what previous studies tell us about the effect of natural disasters on birth outcomes where external disasters induce lower birth weights (Currie and Rossin-Slater, 2013). What I found was that the 2010 birth cohort had the largest birth weight effect with those born in Sichuan in that year being born 335 grams lighter. This is then followed by 2013, 2014, 2008, 2011, 2012, and 2009 respectively. However, although the result shows that although the treated period has significant decreases in birth weight, there seems to be no gradual diminished effect that I would expect. Instead, when examining Figure 3 it actually seems to be that from 2008 to 2014, the birth cohorts actually obtain lower birth weights which then start to rise again from 2015 onwards.

One explanation for this inconsistency could be that there is some other variables or events not controlled for during this period that is affecting the birth weights independent of the 2008 Sichuan Earthquake. This would have to be another exogenous event independent of the individual, provincial, and time variables I controlled for or even events related to the earthquake. The latter could be evens such as continual economic stressors that are compounded each year after the earthquake or post-recovery policies that aim to improve birth weight or relieve stress in the region. One example of this is that there is already evidence that news of economic losses can lead to lower birthweight (Carlson, 2015). Another explanation is that the parallel trend assumption used to utilize the difference-in-difference framework is not fulfilled. The parallel assumption requires that in the absence of treatment, the difference between the treatment and control group is constant over time. Figure 1 shows that before 2008, there were some deviations between Sichuan and Non-Sichuan groups. While the Sichuan birthweights rose in 2005 from 2004 and then dropping back down in 2006, the birth weights for Non-Sichuan seemed to stay relatively the same. These discrepancies are also similarly seen in Figure 2 detailing the Low Birth Weights. This could confound the results and lead to inconclusive findings.

6 Conclusion

Earthquakes are stressful events that can cause health problems long after post-recovery efforts. The long-lasting effects of stress and its corollaries such as PTSD and depression can revurberate across the community in the form of faulty birth outcomes. I examine the effects that the 2008 Sichuan Earhquake had on birth outcomes and how long its effects are felt. By employing a difference-in-difference model by utilizing 2007, the year right before the earthquake as my base year, I found that there were significant differences between birth weights in Sichuan and Non-Sichuan provinces in the years 2008, 2009, 2010, 2011, 2013, and 2014 at the 1% significance level and 2012 at the 5% significance level. I do not find a diminishing effect in the coefficients which went counter to my hypothesis that the earthquake would lead to a direct shock to birth weight that would fade over the years. I propose two hypothesises for this. One is that there are outside exogenous events that occurred in Sichuan or the provinces other than Sichuan and that the parallel assumption for Sichuan and Non-Sichuan birth weights is not fulfilled. This leaves room for future studies to pinpoint the mechanism of low birth weight shocks years following a disaster.

The implication of this study is that there appears to be a period of disruptive birth weights following a large exogenous event such as the Sichuan Earthquake. This could influence policy in several ways. First, accounting for these additional health factors will better assist in developing recovery efforts that acknowledge the prenatal health shocks that natural disasters can impose. Secondly, my findings could advocate for long-term mental health assistance following a disaster that will extend years after the initial shock. In doing so, this period of volatile birth outcomes can be subdued and increase the health of the region overall.

One weakness of my paper is that I am not able to specifically target individuals based on where exactly they were once the earthquake hit. Being able to exact geographic proximity to the earthquake would aid my analysis in not only being more accurate but creating additional insights. Another limitation is the increase of confounding variables when increasing the years post-event. With each year after the disaster, the potential for other variables and exogenous shocks to occur increases leading to problems in controlling for the variables several years afterwards.

7 Appendix: Figures and Tables

Table 1: Birth Weight Measures for Variables of Interest

	Birth weight
	(1)
Panel A: Sichuan	
Before 2008	3.05
	(0.563)
2008 and onwards	2.97
	(0.617)
Difference	.0792
	(.0633)
Panel B: Provinces other than Sichuan	
Before 2008	3.19
	(0.519)
2008 and onwards	3.23
	(0.483)
Difference	-.0394
	(.0129)
N	13319

mean coefficients; sd in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 2: Summary Statistics for Variables of Interest

	(1) Full sample	(2) Male Sample	(3) Female Sample
Birth weight	3.19	3.25	3.13
	(0.513)	(0.517)	(0.502)
Birth year	2006.73	2006.77	2006.69
	(6.680)	(6.623)	(6.745)
Currently in school (yes = 1)	0.44	0.44	0.45
	(0.497)	(0.496)	(0.497)
Male (yes = 1)	0.53		
	(0.499)		
N	16122	8465	7637

mean coefficients; sd in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3: Summary Statistics for Variables of Interest

	(1) Frequency	(2) Percentage
2004	658	6.79
2005	616	6.36
2006	628	6.48
2007	637	6.58
2008	688	7.10
2009	760	7.86
2010	689	7.11
2011	759	7.84
2012	792	8.18
2013	742	7.66
2014	787	8.13
2015	615	6.35
2016	713	7.36
2017	600	6.20
Total	9684	
N	9684	100

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4: Regression Results

	(1) birthweight	(2) lowbirth
sichuan x 2004	-0.0853**	0.0613***
	(-3.28)	(6.34)
sichuan x 2005	0.0248	0.00820
	(0.97)	(0.49)
sichuan x 2006	-0.0799**	-0.0282*
	(-3.09)	(-2.21)
sichuan x 2007	0	0
	(.)	(.)
sichuan x 2008	-0.182***	0.0892***
	(-8.82)	(6.89)
sichuan x 2009	0.0681**	0.0308
	(3.12)	(1.86)
sichuan x 2010	-0.335***	0.199***
	(-12.19)	(18.81)
sichuan x 2011	-0.122***	0.0223
	(-5.36)	(1.92)
sichuan x 2012	-0.0938**	-0.0337**
	(-3.52)	(-3.56)
sichuan x 2013	-0.323***	0.0804***
	(-10.91)	(8.65)
sichuan x 2014	-0.312***	0.126***
	(-13.05)	(10.29)
sichuan x 2015	-0.0804*	0.0214*
	(-2.60)	(2.30)
sichuan x 2016	-0.0581	0.0164
	(-1.65)	(1.22)
sichuan x 2017	-0.0163	-0.0791***
	(-0.68)	(-12.15)
_cons	3.216***	0.0534***
	(2945.95)	(122.51)
N	8598	8598

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5: Regression Results

	(1)	(2)
	birthweight	lowbirth
sichuan x period	-0.150***	0.0740***
	(-16.58)	(17.42)
_cons	3.213***	0.0535***
	(10892.45)	(386.76)
N	8597	8597

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

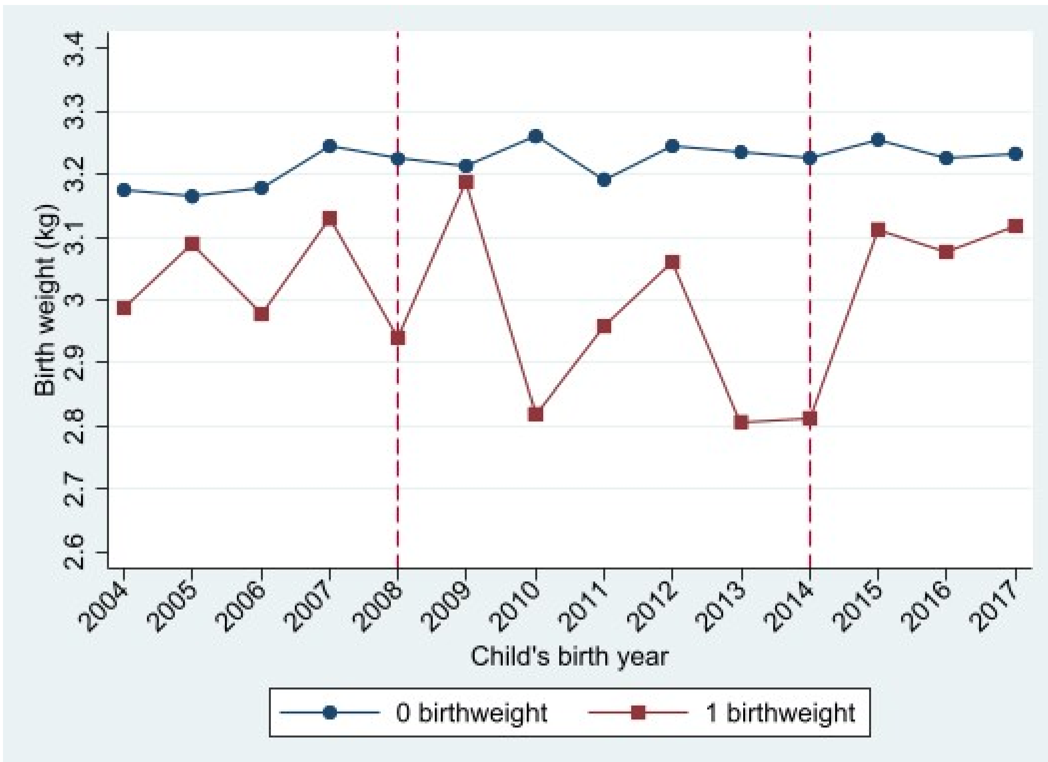

Figure 1: Average Birth Weight Measures by Year

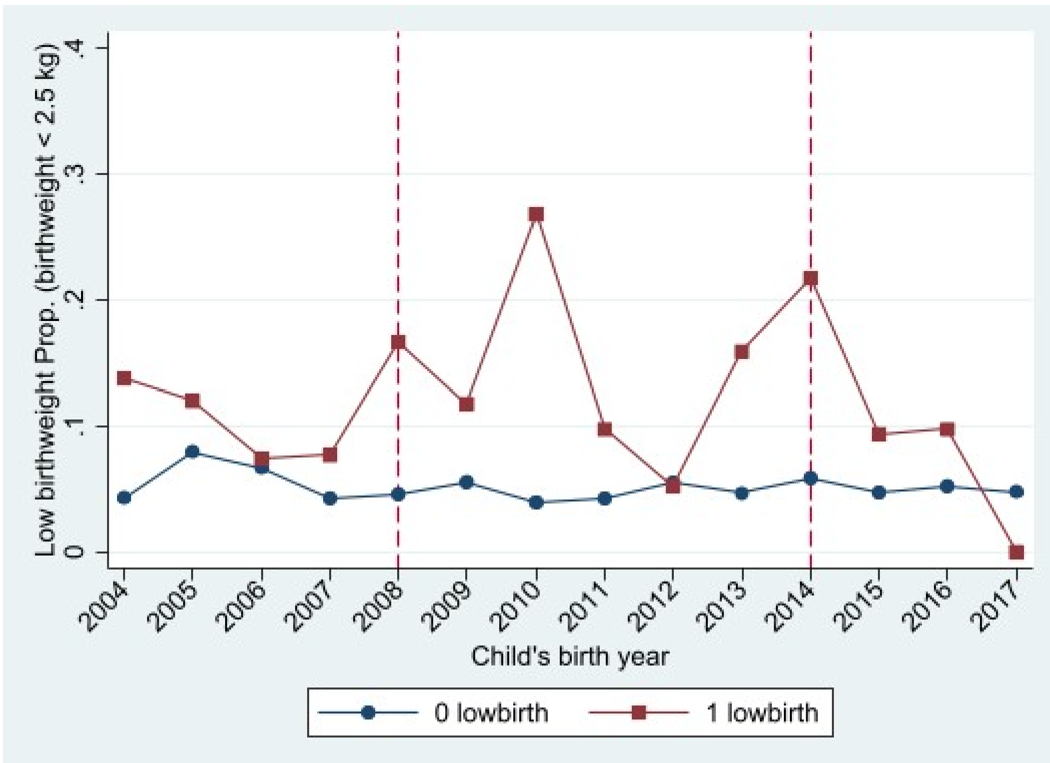

Figure 2: Average Low Birth Weight Measures by Year

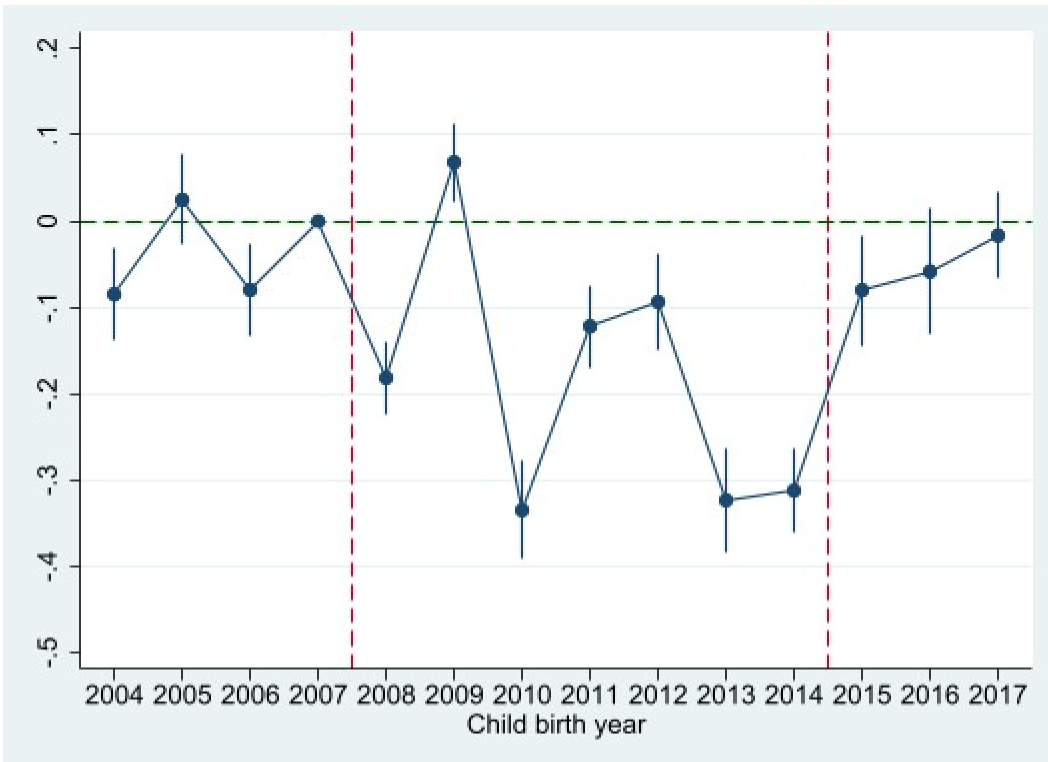

Figure 3: Birth Weight Regression Coefficients by Year

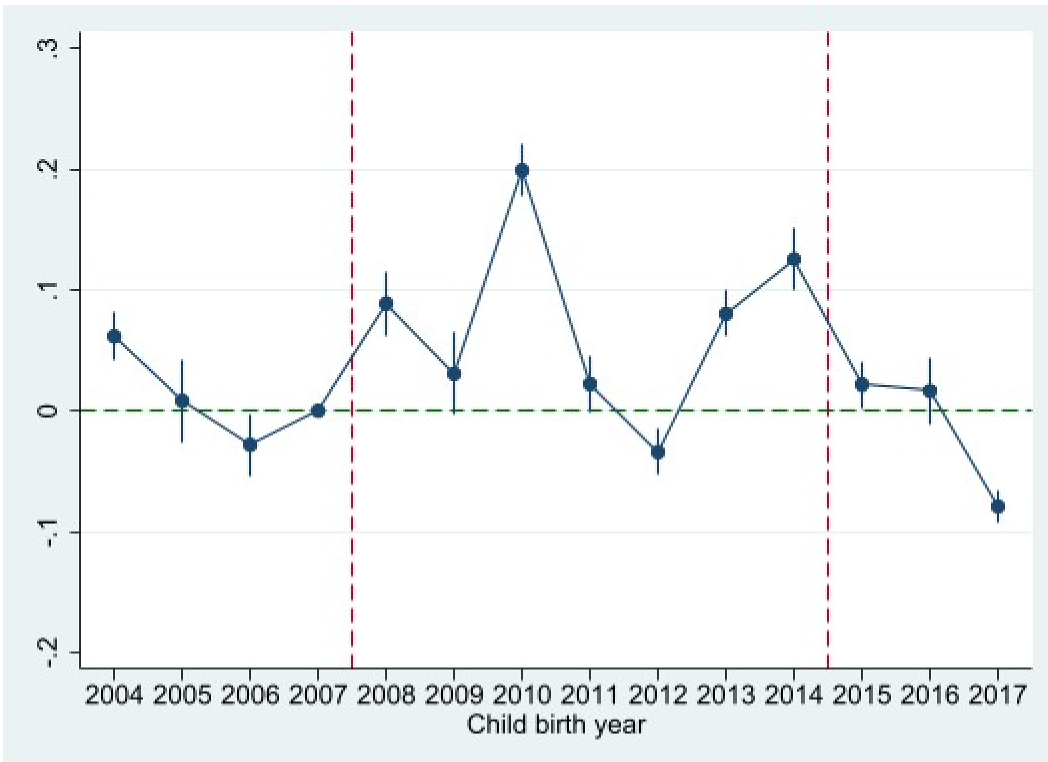

Figure 4: Low Birth Weight Regression Coefficients by Year

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