Determinants of Child Health in Developing Countries – Social, Environmental, and Policy Perspectives

Determinants of Child Health in Developing Countries – Social, Environmental, and Policy Perspectives

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A Dissertation Submitted to the Faculty of

The Harvard T.H. Chan School of Public Health

in Partial Fulfillment of the Requirements

for the Degree of *Doctor of Science*

in the Department of Global Health and Population

Harvard University

Boston, Massachusetts.

May, 2019

Dissertation Advisor: Dr. Jessica Cohen *Author*: Zhihui Li

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Abstract

Child health has been on top of the global health agenda since the Millennium Development Goal era ending in 2015. It is well recognized that a vital and productive society with a prosperous and sustainable future is built on a foundation of healthy child development. The determinants of child health are multifaceted. In this dissertation, several factors affecting children's healthy development are explored.

Using nationally representative data from Jamaica, Chapter 1 focuses on the effects of a health policy on child health, via empirically examining how the national-wide user-fee-removal policy affects children's care seeking behavior and the financial burden their families faced, with an equity focus among children of various wealth levels. I found that in the short-term, the policy deteriorated equity of access to health care for children as the richer families appeared to benefit more; while the equity status improved fast in the medium-to-long-term as the poorer children caught up.

Besides the effects of health programs, I further examine the cost of scaling up the health intervention in Chapter 2, and perform cost-effectiveness analysis (CEA) of a nutritional package program (Yingyangbao [YYB]), which is a nutrient-dense food supplement targeting infants and young children, on children's stunting status in the context of China. Different from the traditional CEA study, I use extended cost-effectiveness analysis (ECEA) method to assess the distributional impact of YYB rollout across provinces and socioeconomic groups. Our result shows that YYB could be a pro-poor intervention that brings substantial health benefits to poor

Chinese children, but with large variations across provinces from as low as ¥800 (Chongqing province) to as high as ¥23,400 (Jilin province).

The determinants of child health are multi-dimensional. Many factors are beyond the reach of health sector, and require multisectoral effort to support childhood development. In Chapter 3, I assess the impact of an environmental factor on child health, via examining how prenatal exposure to sand-and-dust storms (SDS) affects children's cognitive development using nationally representative data from China. I find prenatal SDS exposure is strongly associated with lower mathematics and word-recognition test scores, as well as additional months to begin speaking in sentences.

Despite the findings of this thesis, more work should be conducted to identify mechanisms behind the findings, such as the scientific pathway for pollutant to affect cognitive development.

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Acknowledgements

Firstly, I would like to express my sincere gratitude to my advisor Dr. Jessica Cohen for the continuous support of my doctoral study and related research, for your patience, motivation, and immense knowledge. Your guidance helped me in all the time of research and writing of this thesis. You also devoted much of her precious time to help me obtaining funding to support my thesis. I could not have imagined having a better advisor and mentor for my doctoral study.

Besides my advisor, I would like to thank the rest of my thesis committee: Prof. Wafaie Fawzi and Dr. Stéphane Verguet, for the insightful and invaluable comments they provided, the hard questions they raised to widen the perspectives of my research, the tremendous time they contribute to help me editing, revising, and polishing my thesis. The connection with you is one of the most precious treasure I have obtained during my doctoral program.

Meanwhile, I also want to express my sincere gratitude to Dr. Lincoln Chen, Dr. Chunling Lu and Prof. Subu Subramanian for the support on my research beyond thesis. There is no chance for me to reach my current achievements without their instruction and support. I cannot tell how much time you have spent tutoring me on the methods of statistical analysis, writing STATA code, drafting papers, and connecting me with the well-established figures. Your knowledge and vision is always driving me towards the frontier of the academic world. You are not only my academic tutors, but also tutors for my life. At this moment, I cannot say enough "thank you" to you all.

I cannot smoothly finish my doctoral degree, without the help of Barbara Heil and Allison Gallant. You are so helpful in distributing education and career information, making logistic arrangements, and answering all my questions from the very moment when I entered the master program in 2012.

Lastly, I have a special thanks to my family. I cannot express how grateful I am to my mother, father, mother-in-law, and father-in-law. You have sacrificed your “happy lives” in China and come to this unfamiliar country to help me with everything you could. I really appreciate it and will remember your effort for my rest of life! I would like to give my special appreciation to my beloved husband, Mingqiang Li, who graduated from our department in 2015. You are the lighthouse navigating my way in both the academic and the non-academic world. I don’t know how my life would be without you. At the end, I want to thank my daughters. Thank you for being the sunshine in my life. You are the best “refresher” when I am tired.

Introduction

The determinants of child health are multifaceted. Many previous studies have constructed and described the structural and intermediary determinants of child health.(Blair, Stewart-Brown, & Waterston, 2010; Kerber et al., 2007; Kingsley, Townsend, Henderson-Wilson, & Bolam, 2013; Shonkoff, Richter, Gaag, & Bhutta, 2012) Osorio A et al. has developed a comprehensive conceptual framework presenting the determinants of child health(Osorio, Romero, Bonilla, & Aguado, 2018), which was based on the UNICEF conceptual framework for chronic malnutrition (Farrie & College, 2017; UNICEF, 2015), the conceptual framework proposed by Mosely and Chen (Mosley & Chen, 1984), and the conceptual framework of the WHO commission on Social Determinants of Health (Benach et al., 2010). In Osorio A et al.'s framework, structural and intermediary determinants of child health were described at different levels of analysis, including child, mother, household, and community levels. The structural determinants at community level included socioeconomic determinants, cultural context, participation, policy, programs and governance.(Osorio et al., 2018) Based on this framework, the first two chapters of this thesis aims to conduct in-depth analysis on three of the structural determinants at community level, which are socioeconomic factors, policies, and programs - In Chapter 1, I will examine how a health policy affects health behavior- and financial- outcomes with an equity perspective based on socioeconomic context. In Chapter 2, I will examine how a health program affects child development, with an equity perspective and a cost-effective focus.

Beyond the interweaving factors described in the traditional frameworks, the UN Environment and World Resources Institute have been calling attention on the consequences of environmental compartments on human health for decades. (UN Environment, 2018; Von Schirnding, 2002;

World Resources Institute, 2018) Such efforts were strongly supported by World Health organization, UNICEF, and other influential international organizations.(Bruce, Perez-Padilla, & Albalak, 2000; UNICEF, 2018; World Health Organization, 2016) In recent years, increasing conceptual frameworks have included environmental factors as key determinants of child health.(Briggs, 2008; Goldfeld et al., 2018; Northridge, Sclar, & Biswas, 2003; Soobader, Cubbin, Gee, Rosenbaum, & Laurenson, 2006) In the third chapter of this thesis, we will look beyond the reach of health sector and show the readers how environmental factors could affect child health in a more profound way than many health policies and health programs. This analysis aims to provide a new perspective on how to improve child health.

To investigate the impacts of health policy, health program, socioeconomic determinants, and environmental factors on child health, I develop the following analysis: In Chapter 1, I will investigate the effectiveness of a nation-wide user-fee-removal policy on children's care seeking behavior and the financial burden their families faced in the context of Jamaica. In Chapter 2, I will present an extended cost-effectiveness analysis to assess the cost-effectiveness and equity impact of a nutritional package rollout in China across provinces and socioeconomic groups. In Chapter 3, I develop a quasi-experimental study design to assess the impact of an environmental factor—prenatal exposure to sand-and-dust (SDS) storms—on children's cognitive development in the context of China.

A large literature has documented the profound impact health policies can have on children's health. (Bredenkamp, 2008; Halfon & Hochstein, 2002; Marmot, Friel, Bell, Houweling, & Taylor, 2008; Victora, Habicht, & Bryce, 2004). Discussion and research on the influence of user-fee-removal policy has been ongoing for decades, with a majority of the evidence pointing toward user fees' increasing households' health expenditures and decreasing equitable access to health services.(Burnham, Pariyo, Galiwango, & Wabwire-Mangen, 2004; Gordon-Strachan et al., n.d.; Masiye, Chitah, & McIntyre, 2010; Nabyonga et al., 2005; Nabyonga Orem, Mugisha, Kirunga, Macq, & Criel, 2011; Pariyo et al., 2009; V Ridde, Haddad, & Heinmüller, 2013; Xu et al., 2006) Several Latin American and the Caribbean (LAC) countries have experienced removal or introduction of user fees since 1980, yet few studies have provided concrete evidence regarding the impact of user–fee–removal policy on healthcare utilization and household health expenditures in the LAC region (Bratt, Weaver, Foreit, De Vargas, & Janowitz, 2002; Campbell & Adella, 2013; Institute TCPR, 2013; International Labour Office, 2010; University of the West Indies (Mona & Alexis, 2012) The Chapter 1 of this dissertation focuses on the context of Jamaica, an upper-middle-income LAC country where the health policy has been wavering between advocating or criticizing user fees over the past several decades since 1960s. In this chapter, I use nationally representative data from Jamaica Survey of Living Conditions [JSLCs] (Planning Institute of Jamaica, 2017) to test the following three hypotheses: First, user–fee–removal can increase healthcare utilization among children, because it eliminates an important barrier to health care access. Second, user–fee–removal reduces household health expenditures in families with sick children, especially for the poorest households. Third, the immediate impact of the policy may vary between children from poor families and children from better–off families and could also be different in the medium– to long–term.

While analyzing the influence of user-fee-removal policy on child health, we notice that most of the counterarguments towards the implementation of user-fee-removal policy is regarding its costs.(Campbell & Adella, 2013; Chao, 2013; Meessen et al., 2011) Some studies found evidence that costs of user-fee-removal or user-fee-reduction policies might vary greatly by socioeconomic groups with some of them found the costs would be higher among the disadvantaged groups.(Litvak, n.d.; McPake, Brikci, Cometto, Schmidt, & Araujo, 2011; V Ridde et al., 2013; Valéry Ridde, Robert, & Meessen, 2012). This study, although intended to systematically assess the cost-effectiveness of user-fee-removal policy with an equity perspective, is limited by the availability of cost data. Yet with full recognition of the importance of costs in the decision-making and priority-setting process, I will adopt a newly developed method to analyze the equity implication and cost-effectiveness of a health program in Chapter 2– extended cost-effectiveness analysis.(Verguet, Kim, & Jamison, 2016). This Chapter is based on the context of China where a nutritional program (Yingyangbao [YYB]), a nutrient-dense food supplement targeting infants and young children, has been piloted since 2001 and has been proposed as one key intervention to improve nutritional status for rural and poor regions in China.(Ministry of Education of the People's Republic of China, n.d.; Outlook Weekly, n.d.; The State Council of the People's Republic of China, n.d.) Although many previous studies have investigated the effectiveness of YYB on improving children's nutritional status(Q. Zhang, Sun, Jia, & Huo, 2015), little work has been done to assess the cost-effectiveness of YYB delivery and its potential distributional impact across China's provinces and socioeconomic groups. In this chapter, we employ extended cost-effectiveness analysis (ECEA) methods (Verguet et al., 2016; Verguet, Laxminarayan, & Jamison, 2015) to study the cost-effectiveness of YYB rollout in China across provinces and socioeconomic groups, as well as the equity impact of this program.

Beyond health policies and health programs, an increasing volume of literature show that factors beyond the health sector might also affect child health in a profound way.(National Research Council, 2004) Environmental factors have gained growing attention during the past decade and are widely included in conceptual frameworks of child health developed in recent years.(Briggs, 2008; Bruce et al., 2000; Goldfeld et al., 2018; Horton et al., 2014; Northridge et al., 2003; Smith, Corvalán, & Kjellström, n.d.; Soobader et al., 2006) In Chapter 3, we examined a worldwide environmental phenomenon that affected roughly two billion people in the word - sand and dust storms (SDSs). Globally, there has been mounting evidence that SDSs are associated with adverse effects on child health, including increases in mortality and the risk of respiratory, cardiovascular, and cardiopulmonary diseases.(Pope, Ezzati, & Dockery, 2009; Rashki et al., 2012; X. Zhang et al., 2016) Several studies show evidence that prenatal exposure to dust events significantly lowers birth weight, reduces gestational time, and increases infant mortality.(Adhvaryu Prashant Bharadwaj James Fenske Anant Nyshadham Richard Stanley, Benjamin, Fisher, & Turner, 2016; Baek, Altindag, & Mocan, 2015) Although previous studies have demonstrated short-term effects of SDSs on infants' physical health, the longer-term effects of SDSs on children's cognitive function remained unexplored. Moreover, previous studies are mostly observational, and the relationships between environmental factors and health effect could be biased by unobserved confounders that are correlated with both exposure to air pollutants and child outcomes, such as regional economic conditions, agricultural outputs, etc. Our study attempts to overcome this limitation with a rigorous quasi-experimental design. We make use of the fact that annual fluctuations in the incidence of SDS in China are largely unpredictable, and use a region- and year- fixed effects model to compare the cognitive function of children born in the same region and year but with varying incidence of prenatal SDS exposure because of different gestational timing.

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Chapter 1

User–fee–removal improves equity of children's healthcare utilization and reduces families' financial burden – evidence from Jamaica

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Published on June 19th, 2017 in *Journal of global health*

Full citation:

Li Z, Li M, Fink G, Bourne P, Bärnighausen T, Atun R. User–fee–removal improves equity of children's health care utilization and reduces families' financial burden: evidence from Jamaica. *Journal of global health*. 2017 Jun;7(1).

Abstract

Background The impact of user–fee policies on the equity of healthcare utilization and households' financial burdens has remained largely unexplored in Latin American and the Caribbean, as well as in upper–middle–income countries. This paper assesses the short– and long–term impacts of Jamaica's user–fee–removal for children in 2007.

Methods This study utilizes 14 rounds of data from the Jamaica Survey of Living Conditions (JSLC) for the periods 1996 to 2012. JSLC is a national household survey, which collects data on healthcare utilization and among other purposes for planning. Interrupted time series (ITS) analysis was used to examine the immediate impact of the user–fee–removal policy on children's healthcare utilization and households' financial burdens, as well as the impact in the medium– to long–term.

Results Immediately following the implementation of user–fee–removal, the odds of seeking for healthcare if the children fell ill in the past 4 weeks increased by 97% (odds ratio 2.0, 95% confidence interval [CI] 1.1 to 3.5, *P*=0.018). In the short–term (2007–2008), healthcare utilization increased at a faster rate among children not in poverty than children in poverty; while this gap narrowed after 2008. There was minimal difference in healthcare utilization across wealth groups in the medium–to–long–term. The household's financial burden (health expenditure as a share of household's non–food expenditures) reduced by 6 percentage points (95% CI: –11 to –1, *P*–value= 0.020) right after the policy was implemented and kept at a low level. The difference in financial burden between children in poverty and children not in poverty shrunk rapidly after 2007 and remained small in subsequent years.

Conclusions User–fee–removal had a positive impact on promoting healthcare utilization among children and reducing their household health expenditures in Jamaica. The short–term and the

medium–to–long–term results have different indications: In the short–term, the policy deteriorated the equity of access to healthcare for children, while the equity status improved fast in the medium–to–long–term.

1.1 Introduction

User fees refer to charges related to health services at the point of use. Such fees have been used to generate revenues for healthcare providers, reduce healthcare financing burden on governments and encourage clients to use health services more judiciously.(1) Historically, both the World Bank and the International Monetary Fund (IMF) have promoted user fees.(2,3) Yet evidence points to negative effects on equitable access to health services, and arguably increased households' health expenditures. Studies from Kenya, Tanzania, Burkina Faso, Niger, Democratic Republic of Congo, Lesotho, and Papua New Guinea have found that the introduction or increase of user fees significantly reduced health service utilization, with the poor and those in rural areas disproportionally disadvantaged because of the high financial burden.(4–11) Recognizing user fee as a barrier to access health services, the WHO passed resolutions 58.31 and 58.33 in 2005, urging member states to remove user fees in order to achieve Universal Health Coverage (UHC).(12) UNICEF also committed to support the removal of user fees for children and pregnant women.(13)

The Latin American and the Caribbean (LAC) countries have wavered between advocating or criticizing user fees over the past three decades. In the 1980s, user fees were introduced in Honduras, Jamaica, and Peru.(14) In the 2000s, Jamaica and Ecuador removed user fees in the public health sector.(15) Although a handful of studies have assessed the effects of user–fees on the quality of patient care, the work environment of health professionals, and the delivery of health services, few studies have provided concrete evidence regarding the impact of user–fee–removal policy on healthcare utilization and household expenditures in the LAC region.(16–18)

Our study focuses on Jamaica, an upper–middle–income country in the LAC region. **Box 1** introduces Jamaica's health system. In May 2007, the Government of Jamaica implemented a new policy that removed user fees for all children aged 0–18 years in the public sector, except for the University Hospital of the West Indies (see **Box 2**). Our study aims to evaluate the impact of user–fee–removal on children's healthcare utilization and household health expenditure both on average and across income groups.

In our study, we tested three hypotheses: First, user–fee–removal will increase healthcare utilization among children, because it eliminates an important barrier to access health care. Second, user–fee–removal will reduce household health expenditures in families with sick children, especially for the poor households. Third, the immediate impact of the policy may vary between children from poor families and children from better–off families and could also be different in the medium– to long–term.

Box 1. Background information on Jamaica's health system.

Jamaica is an upper–middle–income country with a Gross Domestic Product (GDP) per capital of US$ 8467 (constant 2011 international PPP adjusted US$) and a total population of 2.7 million in 2014. In 2014, the unemployment rate of the total labor force was 13.2%.(22)

Despite moderate improvements in life expectancy, infant mortality, and under–five mortality, Jamaica has not reached the MDG4 and MDG5 targets. Before the implementation of user–fee–removal policy in 2007, Jamaica's maternal mortality increased from 79 per 100 000 live births in 1990 to 91 per 100 000 live births in 2006. The under–5 mortality rate decreased by 36% from 30.6 per 1000 live births in 1990 to 19.5 in 2006. Infant mortality rate fell by 34% from 25.4 per 1000 live births in 1990 to 16.7 in 2006.(22)

Jamaica's health system is financed through a mix of public and private sources. The government spends around 6% of the GDP on health. Total health expenditure per capita in 2013 was US$ 512 (constant 2011 international PPP–adjusted US$). In 2013, the government expenditure accounted for 57% of the total health expenditure and out–of–pocket payments contributed 25%, while other private sources, such as private health insurance, accounted for 18% of the total.(118)

Jamaica's public health sector is the primary provider of public health and hospital services and comprises approximately 5,000 hospital beds across secondary and primary care facilities (around 1.8 hospital beds per capita). The private sector consists of approximately 200 beds (around 0.1 hospital beds per capita) and dominates ambulatory services and the provision of pharmaceuticals.(118)

Box 2. Background information on Jamaica's user–fee–removal policy.

Historically, Jamaica's political parties have used promise of better and lower cost healthcare services in campaigns to seek for votes. The removal of user fees between 2007–2008 in public health facilities was a practice of the campaign promise: When the People's National Party (PNP) was in government, it introduced the no–user–fee policy for children aged 0–18 years and considered extending no–user–fees to adults. During the General Election in Jamaica in September, 2007, the Jamaica Labour Party (JLP) made the campaign promise to remove user fees for all patients in the public health sector. After the JLP party won the 2007 General Elections, the JLP administration fulfilled its campaign promise by removing user fees in the public health sector, except at the University Hospital of the West.

In Jamaica, adjustments to user fees is nothing new, as this practice dates back to the 1960s (**Box Table 1**). Over the past five decades, user fees have been abolished and/or altered eight times: In 1968, Jamaica's health authorities began revising its public health sector fee structure. User fees were removed in 1975 and reintroduced in 1984. After 23–years of user–fees in public health facilities, Jamaica abolished user fees in all public health facilities except for the University Hospital of the West Indies: on May 28th, 2007, Jamaica removed user fee for children aged 0–18 years old, and on April 1st, 2008, Jamaica removed user fees for adults.

Box Table 1. User fees changes in Jamaica, 1968–2008

Details	Year	In government (JLP or PNP)
Revised user fees	1968	JLP
Removal of user fees	1975	PNP
Re–introduction of user fees	1984	JLP
Adjustment of user fees (upwards)	1993	PNP
Adjustment of user fees (upwards)	1999	PNP
Adjustment of user fees (upwards)	2005	PNP
Removal of user fees (children aged 0–18 years old)	May 2007	PNP
Removal of user fees – all public patients	April 2008–PRESENT	JLP

Sources: Universal Coverage in Jamaica by Dr. Michael Coombs, Chief Medical Officer, Jamaica modified from Waller (2013) http://www2.paho.org/hq/index.php?option=com_docman&task=doc_view&gid=19100&Itemid=270 . Accessed at 4th May, 2017.

Earlier studies on the impact of user–fee–removal on healthcare utilization and household expenditures have been mostly limited to Africa.(4–10,19) Our study is in a country of Latin America and the Caribbean, with different characteristics from Africa: Most countries in LAC belong to upper–middle– or high–income country groups and are expanding universal health coverage, with substantial social segregation and inequalities in access to healthcare.(20,21) Methods used in earlier studies were largely constrained by data availability, and could not identify a causal relationship between user–fee–removal policy and the changes in healthcare utilization, as well as households' financial burden. We used interrupted time series (ITS) analysis to provide strong evidence for the policy's causal effects. By comparing the changes in outcomes right before and right after the policy change, ITS analysis assumes no changes in other factors that have a potential impact on the outcomes that coincide with the policy of interest. Furthermore, ITS analysis can inform us the immediate, as well as its medium– to long–term impact of a policy.

Evaluating user–fee–removal policy for children has strong policy significance. Of all countries in the LAC region, Jamaica's progress in reaching the Millennium Development Goals (MDGs) target for reducing child and infant mortality has been among the slowest. Between 1990 and 2006, Jamaica's under–5 mortality rate declined by an annual rate of 2%, compared to 5% for countries in LAC and 4% in other upper–middle income countries in the world.(22) Given that child mortality is closely linked to access to health services (23,24), Jamaica's experience can provide evidence for countries aimed at applying user–fee removal to reduce child and infant mortality. We assessed the impact of user–fee–removal policy with an equity dimension, which is a prioritized by the Sustainable Development Goals (SDGs). Our findings would shed light for the other countries on how to achieve health equity in the SDG era.

1.2 Methods

1.2.1 Data sources

This study uses data from the Jamaica Survey of Living Conditions (JSLC) – a nationally representative household survey, which consists of six core modules: demographic characteristics, household consumption, health, education, housing, and social protection. For this paper, we use data from 1996–2012. Health module data were not collected in 2003, 2005 and 2011 surveys, and thus these waves are excluded from the study. We totally used 14 rounds of surveys in this study. Some of the earlier waves are incomplete: for example, the education level of the household head, which is an important control variable in the regression analysis, has 26.9% missing values before 2004. To solve this problem, when conducting ITS analysis, we only presented the regression results using data from 2004–2012 in the main text to ensure the key variables are with high data quality. We provided the ITS regression results using data from 1996–2012 in **Appendix Table 1.2-1.4**.

We excluded the observations interviewed within 4–weeks after the policy implementation date (May 28th, 2007), as it was not possible to identify whether their illness happened before or after the implementation of the policy. Moreover, subjects aged 18 years when the user fee exemption took place, were also excluded from analysis as it was difficult to ascertain whether they we over 18 or under 18 years by the time of policy change.

1.2.2 Outcome variables

We have two types of outcomes: (i) healthcare utilization and (ii) households' financial burden due to healthcare services. As with earlier studies, our measure of healthcare utilization is whether an individual sought care from a health professional if she/he experienced a health problem in the 4–weeks prior to the survey.(25–27) According to the JSLC, health professionals include doctors, nurses, pharmacists, midwives, healers, and other health professionals.(28)

We define households' financial burden as out–of–pocket health expenditures as a share of the household's non–food consumption if the individual experienced a health problem in the 4–weeks prior to the survey.(29) Out–of–pocket health expenditure was defined as expenditures at public/private health centers, public/private hospitals, and costs of medicines purchased from public/private sources, which were not covered by insurance. Healthcare expenditure was considered to be catastrophic when the share of the household's out–of–pocket health expenditure was larger than 40% of the household's non–food consumption.(30)

"People in poverty" was defined as those in the lowest wealth quintile. Utilization gap was defined as the difference in health professional visiting rates between children in poverty and children not in poverty. Gap in financial burden was defined as difference in the likelihood of encountering catastrophic health expenditure between patients from households in poverty and those not in poverty.

1.2.3 Statistical analysis

We used ITS analysis to assess the impact of user–fee–removal on healthcare utilization, financial burden, and equity. With a clear intervention time point, ITS regressions are able to identify both immediate and medium–to–long–term changes in outcomes between the pre– and post–treatment segments, assuming that no other relevant changes that might impact outcomes coincide with the policy of interest. With this feature, ITS regressions enable examination of any significant changes after the introduction of a new policy.

Our data in 2007 is from May to September, covering the exact date when the policy was implemented on May 28th, 2007. We can thus directly assess the changes in healthcare utilization and financial burden right before and right after the implementation of the user–fee–

removal policy, but also analyze medium–to–longer–term impact of the policy. The ITS model used in our analysis is represented as:

$$Y_{it} = \beta x_{it} + \alpha_1 trend_t + \alpha_2 post_t + \alpha_3 trend_t \times post_t + \varepsilon_{it}$$

where: Y_{it} is the dependent variable for an individual observation, subscript *i* refers to the individual case and subscript *t* refers to the time, x_{it} are the individual–level and household–level variables at time *t*. $Trend_t$ is the time variable, indicating the number of years from 2000. For example, we use 4 to represent the year 2004. $Post_t$ is the time dummy for being in the post–treatment period, estimating the immediate change of outcome when the policy occurred. The interaction term, $trend_t \times post_t$, measures the change in trend in the post–intervention segment. To further capture the policy's impact on the equity of healthcare utilization and household's financial burden, we stratify the analysis by children in poverty versus children not in poverty. Such stratification allows us to identify the effects of policy change on children from different wealth levels.

As healthcare utilization is a binary dependent variable, we use both ordinary least squares (OLS) and Logit regression for its analysis.

We conduct two robustness checks to ensure the results are not driven by unobservable confounders. In the first, we assume the removal of user fees in 2007 was targeted at adults over 18. If our estimates were driven by unobserved variables, such as changes in health system capacities, distance to the health facilities, opportunity cost of visiting health facilities, etc., it should also largely reflect on adults. The second robustness check assumes that the user–fee–removal policy was implemented in May 28th, 2006, instead of May 28th, 2007. This test could exclude the possibility that the results are driven by seasonal factors.

1.2.4 Role of the funding source

There was no funding source for this study. The corresponding author obtained access to the JSLC data of year 1996–2012 via the Derek Gordon Databank. The corresponding author had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis as well as the decision to submit for publication.

1.3 Results

Table 1.1 summarizes the individual–level and household–level characteristics in 2004, 2006, 2008, 2010 and 2012. These characteristics remain stable over years. For example, the mean age of the respondents ranges from 39.0 to 41.7 years old; male accounts for 39% to 41% of the sample, average households' wealth quintiles range from 3.0 to 3.2.

Table 1. 1 Description of key variables

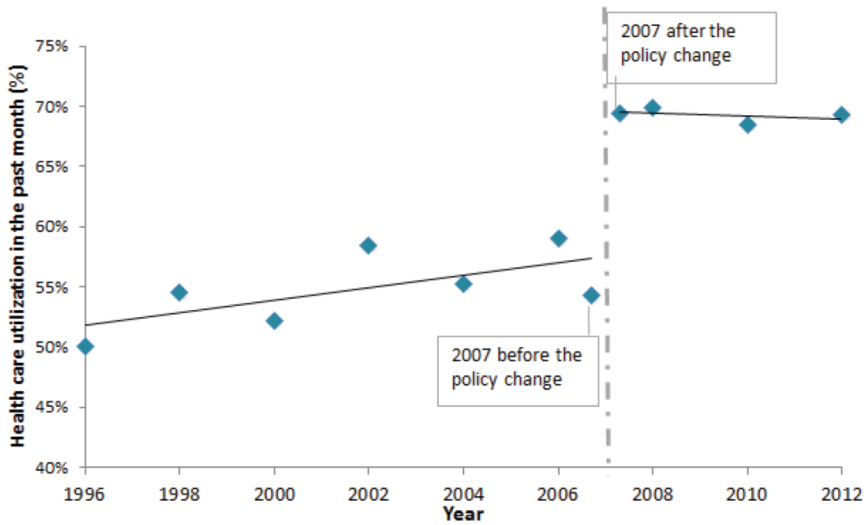
	2004	**2006**	**2008**	**2010**	**2012**
Individual's characteristics					
Age	40.7	41.7	39.1	39.0	40.5
Male	37.0%	39.0%	39.0%	40.0%	41.0%
Respondent is the head of the household	42.0%	42.0%	43.0%	41.0%	43.0%
Covered by private or public health insurance	23.0%	21.0%	23.0%	19.0%	20.0%
Household's characteristics					
Number of household members	4.2	4.2	4.2	4.0	4.0
Live in urban areas	24.0%	22.0%	31.0%	29.0%	23.0%
Live in rural areas	60.0%	59.0%	51.0%	52.0%	59.0%
Live in towns	16.0%	19.0%	19.0%	19.0%	18.0%
Education level of the household head:					
No education	3.0%	4.0%	2.0%	4.0%	2.0%
Primary education (Grade 1–6)	37.0%	32.0%	24.0%	27.0%	26.0%
Secondary education (Grade 7–13)	53.0%	57.0%	61.0%	58.0%	57.0%
Higher education	7.0%	7.0%	13.0%	11.0%	15.0%

The education level of the household is obtained through the following approach: If the education level of the household head is available, we used it directly; if not available, we used the education level of the spouse of the household head instead; if still not available, we used the maximum education level of the household member instead; if still not available, we used the maximum education of the dwelling instead.

1.3.1 Healthcare utilization

Figure 1.1 shows children's healthcare utilization over time, which largely increased from 54.2% before the implementation of user–fee–removal policy to 69.4% after the policy change in 2007. The rates remained high in the years from 2007 to 2012, ranging from 68.5% to 69.9%.

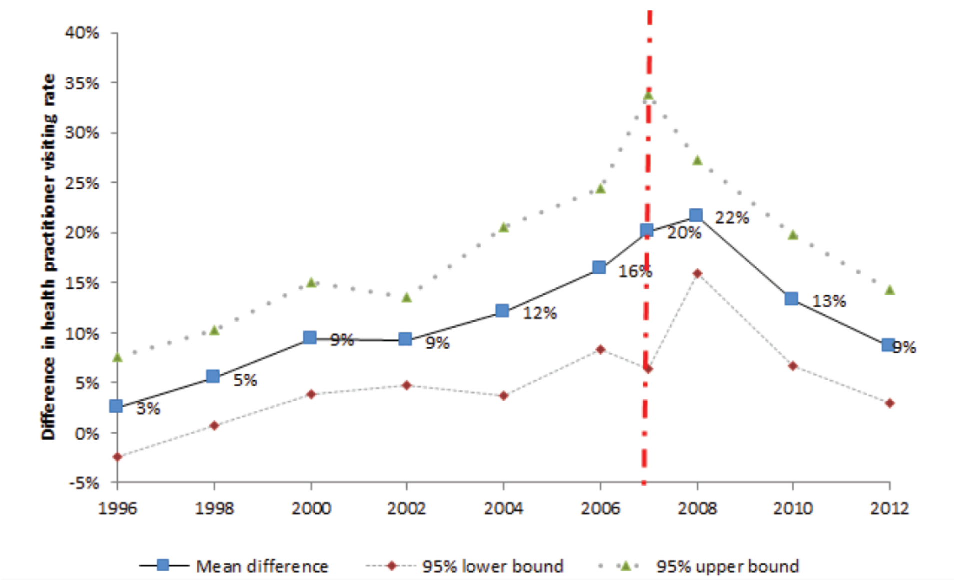
Figure 1. 1 Healthcare utilization among under-18 children fell ill in the past 4 weeks



To generate this figure, we split the 2007 sample into two parts–the sample interviewed before the implementation of user-fee-removal policy and the sample interviewed four weeks after it. The observations numbers in the JSLC surveys vary by year (Most years have observation numbers between five thousand and eight thousand. For several years, the observation number is above fifteen thousand, such as 2008, and 2012). To increase the observation numbers involved in the generation of each data point in the figure above, we combined data from 1996 and 1997, 1998 and 1999, 2000 and 2001, 2001 and 2002, 2009 and 2010. Sample weight is applied to all available years.

Figure 1.2 presents the utilization gap–the difference in health professional visiting rates between children in poverty and children not in poverty–with 95% CI. Before the policy change in 2007, the utilization gap gradually rose from 2.6% to 16.4% between 1996 and 2006. In the short–term (2007–2008), the utilization gap further increased and reached 21.7% in 2008. However, this trend reversed in the medium–to–long–term (after 2008) as the children in poverty increased their utilization at a higher rate than the children not in poverty. The utilization gap shrank by nearly two–thirds between 2008 and 2012, and reached 8.7% in 2012.

Figure 1. 2 The difference in healthcare utilization between children in poverty and children not in poverty, among under-18 children fell ill in the past 4 weeks



The observations numbers in the JSLC surveys vary by year (most years have observation numbers between five thousand and eight thousand. For several years, the observation number is above fifteen thousand, such as 2008, and 2012). To increase the observation numbers involved in the generation of each data point in the figure above, we combined data from 1996 and 1997, 1998 and 1999, 2000 and 2001, 2001 and 2002, 2009 and 2010. Subjects under 18 years old in 2007 interviewed before May 28th, 2007 are combined to year 2006 to prevent losing observations. Sample weight is applied to all available years.

Table 1.2 presents the ITS regression results among individuals aged less than 18–years old (columns 1–3) and children aged less than 5–years old (columns 4–6). Column 1 and 4 shows the results for all children of that age group. Columns 2 and 3, as well as columns 5 and 6, stratify the children by wealth and show the regression results respectively.

The implementation of user–fee–removal policy in 2007 immediately and significantly increased the odds of healthcare utilization by 97% (OR 2.0, 95% CI 1.1 to 3.5, *P*=0.018) among all children aged less than 18 years. The stratified regressions show that children not in poverty significantly increased the odds of seeking for healthcare when fell ill by 82% (OR 1.8, 95% CI 1.1 to 3.0, *P*=0.005). There is no significant change in healthcare utilization among children in poverty. A joint F–test in columns 2 and 3 rejected the null hypothesis that two models are the same (F=135, *P* <0.001).

Table 1. 2 ITS regression on the impact of user–fee–removal policy on healthcare utilization among children less than 18–years and children aged less than 5–years (Logit regression, presented in odds ratio and 95% CI)

	Under 18 years old			Under 5 years old		
	(1) Overall (OR, 95% CI)	(2) In poverty (OR, 95% CI)	(3) Not in poverty (OR, 95% CI)	(4) Overall (OR, 95% CI)	(5) In poverty (OR, 95% CI)	(6) Not in poverty (OR, 95% CI)
Trend	1.09 (1.00, 1.18)§	0.9 (0.73, 1.12)	1.13 (1.01, 1.27)§	1.16 (0.95, 1.42)	1 (0.67, 1.48)	1.16 (0.96,1.42)
Post	1.97 (1.12, 3.46)§	1.47 (0.23, 9.45)	1.82 (1.10, 3.00)§	4.54 (0.98, 21.16)‖	7.17 (0.44, 117.88)	2.93 (0.70, 12.20)
Post* trend	0.95 (0.89, 1.02)	1.08 (0.83,1.40)	0.94 (0.87,1.02)	0.85 (0.67, 1.06)	0.87 (0.54, 1.42)	0.88 (0.73, 1.05)
Age	0.95 (0.94, 0.97)‡	0.98 (0.90, 1.06)	0.95‡ (0.93, 0.97)	0.84 (0.79, 0.90)‡	0.84 (0.73, 0.95)‡	0.84 (0.79, 0.89)‡
Male	0.95 (0.82, 1.09)	0.9 (0.52, 1.55)	0.98 (0.79, 1.21)	0.95 (0.74, 1.23)	0.78 (0.39, 1.57)	1.04 (0.78, 1.39)
Enrolled in private health insurance	1.70 (1.18, 2.44)‡	1.45 (0.49, 4.31)	1.82 (1.13, 2.93)§	1.11 (0.76, 1.62)	0.11‡ (0.02, 0.56)	1.48 (0.81, 2.69)
Enrolled in public health insurance	1.91 (0.83, 4.43)	4.01‡ (1.71, 9.44)	1.67 (0.63, 4.46)	2.53 (0.98, 6.52)‖	13.16 (3.77, 45.93)‡	1.65 (0.50, 5.45)
Wealth (Poorest quintile is the reference group):						
Poorer	1.18 (0.90, 1.55)			1.32 (0.75, 2.33)		
Middle	1.55 (1.27, 1.90)‡			1.75 (1.10, 2.78)§		
Richer	1.90 (1.34, 2.69)‡			2.11 (1.16, 3.81)§		
Richest	1.72 (1.17, 2.55)‡			2.33 (1.10, 4.96)§		
Household size	0.97 (0.93, 1.01)‖	0.95 (0.85, 1.07)	0.95 (0.89, 1.01)‖	0.97 (0.90, 1.05)	0.96 (0.79, 1.17)	0.95 (0.87, 1.03)
Place of residence ("rural" is the reference group):						
Urban	1.18 (0.77, 1.82)	1.01 (0.44, 2.32)	1.29 (0.79, 2.11)	1.11 (0.70, 1.76)	1.4 (0.49, 3.99)	1.14 (0.70, 1.83)
Town	1.06 (0.65, 1.71)	0.92 (0.50, 1.70)	1.13 (0.72, 1.78)	1.04 (0.58, 1.87)	0.62 (0.18, 2.12)	1.29 (0.75, 2.21)
Education level of the head of the household ("no education" is the reference group)†:						
Primary education	0.61 (0.48, 0.76)‡	0.25 (0.14, 0.45)‡	1 (0.65, 1.54)	0.55 (0.40, 0.76)‡	0.17 (0.07, 0.42)‡	1.19 (0.75, 1.88)
Secondary education	0.66 (0.45, 0.97)§	0.34 (0.22, 0.53)‡	0.95 (0.51, 1.75)	0.76 (0.51, 1.12)	0.36 (0.19, 0.70)‡	1.12 (0.63, 1.98)
Higher education	0.56 (0.36, 0.89)§	0.44 (0.19, 1.02)‖	0.76 (0.41, 1.40)	0.67 (0.40, 1.10)	0.42 (0.20, 0.87)§	0.97 (0.51, 1.84)
cons	1.00 (0.56, 1.77)	5.78 (1.18, 28.39)§	0.92 (0.48, 1.74)	0.83 (0.19, 3.57)	5.94 (0.42, 84.18)	0.95 (0.23, 3.87)
N	1931	441	1488	959	237	722

The design of JSLC is a two–stage stratified random sampling design, with the first stage a selection of Primary Sampling Units (PSUs), and the second stage a selection of dwellings. Standard errors are clustered at sampling region level, which is one level above the PSUs. Two PSUs were grouped into one sampling region. The robust standard errors are reported in parentheses. †The education level of the household is obtained through the following approach: If the education level of the household head is available, we use it directly; if not available, we use the education level of the spouse of the household head instead; if still not available, we use the maximum education level of the household member instead. ‡Significance at the 1% level. §Significance at the 5% level. ‖Signficance at the 10% level.

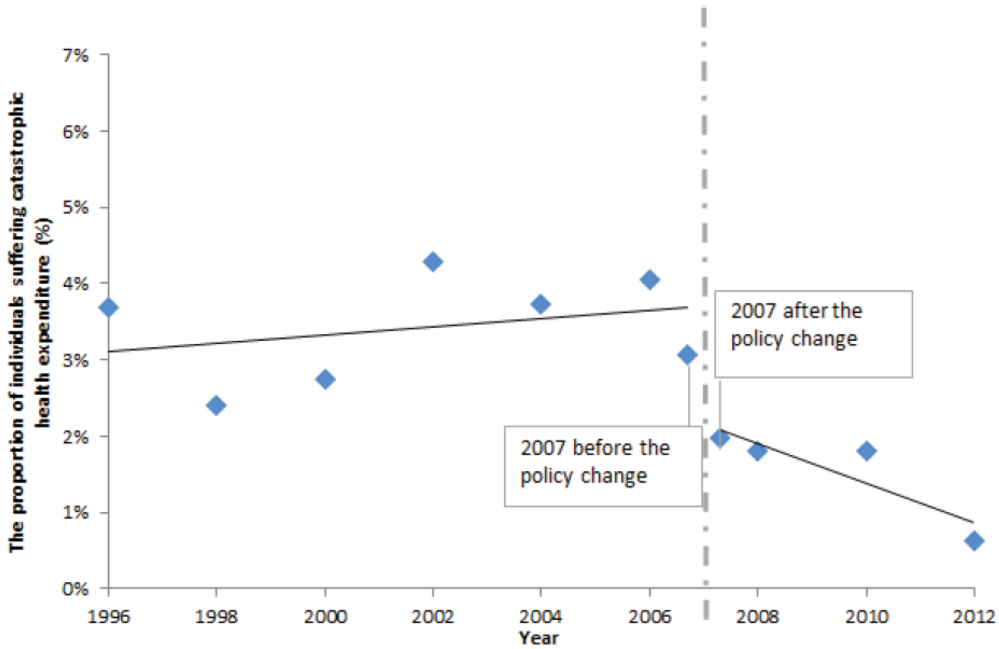
Columns 4–6 are the results for children aged under 5–years. As shown in column 4, the odds of healthcare utilization increased by 354% (OR: 4.5, 95% CI 1.0 to 21.2 p=0.054) after the policy change among all children aged less than 5–years. The stratified results in column 5 and 6 show that the magnitudes of "post" are large for both wealth groups, yet the effects are insignificant. A joint F–test on the results shown in columns 5 and 6 rejected the null hypothesis that two models are the same (F=586, P <0.001).

The results from the OLS regressions are very consistent with the ITS regression results (see **Appendix Table 1.1**). These results are also consistent with the regression results with data from 1996 to 2012 (see **Appendix Table 1.2** and **1.3).**

1.3.2 Healthcare expenditures

Figure 1.3 presents the percentage of households with sick children suffering from catastrophic health expenditure. We observe that the proportion of households with sick children suffering from catastrophic health expenditure immediately reduced from 3.1% to 2.0% after the policy change in 2007. The percentage of households with sick children suffering from catastrophic health expenditure continued to decline between 2007 and 2012. In 2012, only 0.6% of households with children aged less than 18–years encountered catastrophic health expenditure.

Figure 1. 3 The proportion of households with under-18 children suffered catastrophic health expenditure in the 4 weeks preceding the survey if the children fell ill in the past 4 weeks



Note:

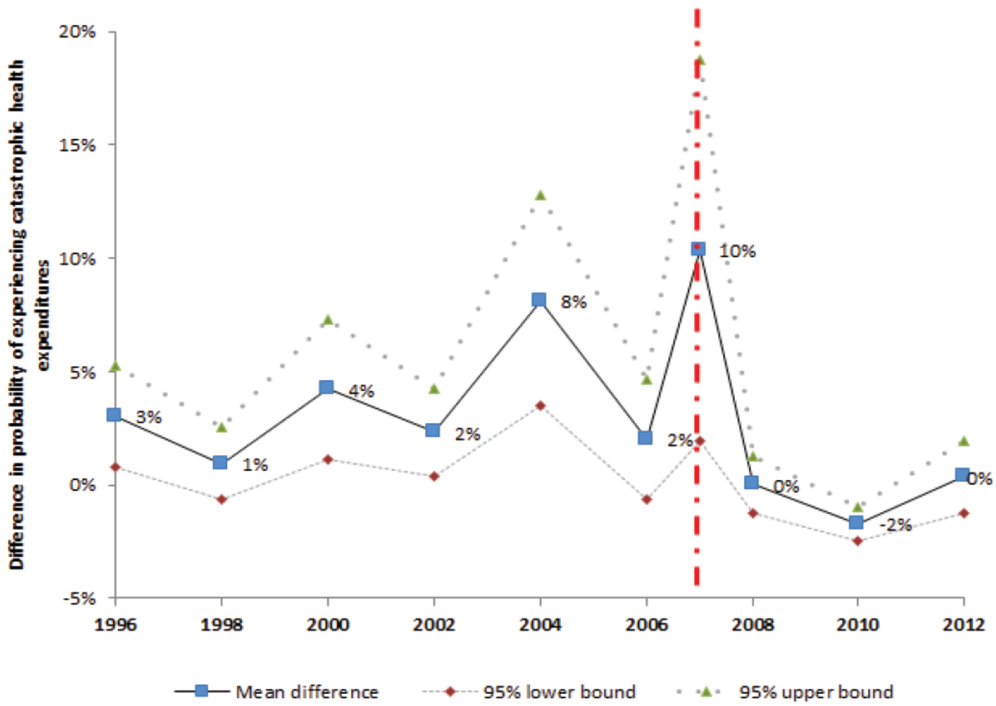
1. To generate this figure, we split the 2007 sample into two parts–the sample interviewed before the implementation of user-fee-removal policy and the sample interviewed four weeks after it. The observations numbers in the JSLC surveys vary by year (most years have observation numbers between five thousand and eight thousand. For several years, the observation number is above fifteen thousand, such as 2008, and 2012). To increase the observation numbers involved in the generation of each data point in the figure above, we combined data from 1996 and 1997, 1998 and 1999, 2000 and 2001, 2001 and 2002, 2009 and 2010. Sample weight is applied to all available years.
2. Healthcare expenditure was considered to be catastrophic when the share of the household's out–of–pocket health expenditure was larger than 40% of the household's non–food consumption

Figure 1.4 presents the financial burden gap, which is the difference between households in poverty and households not in poverty with sick children to encounter catastrophic health expenditures. The financial burden gap reduced rapidly in the short–term (2007–2008) and remained low in the medium–to–long–term. In 2008, households in poverty, for the first time in the year analyzed, became no more likely to encounter catastrophic health expenditures than the households not in poverty. Such a phenomenon is also observed in years 2010 and 2012.

Table 1.3 shows the ITS regression results on the household's financial burden. The first three columns cover children aged less than18–years and the last three columns refer to children aged less than 5–years. The results show that the user–fee–removal policy significantly reduced financial burden by 6.2 percentage points (95% CI –11 to –1, *P*=0.02) among children under 18–years. The stratified regressions show that the policy change reduced the financial burden significantly by 12.1 percentage points (95% CI –22 to –2, *P*=0.02) among children in poverty and 5 percentage points (95% CI –12 to 2, *P*=0.133) among children not in poverty.

Columns 4–6 are the results for children aged less than 5–years. As shown in column 4, the share of out–of–pocket healthcare expenditure in household's non–food consumption reduced by 7.1 percentage points (95% CI –15 to 1, *P*=0.075) after the policy change among all children aged less than 5–years. The stratified results in columns 5 and 6 show negative, yet insignificant magnitudes of "post". Joint F tests on the results shown in columns 2 and 3, as well as columns 5 and 6, rejected the null hypothesis that the models are the same (F=194, *P* <0.001; F=167, *P* <0.001). These results are consistent with the regression results using data from year 1996 to 2012 (see **Appendix Table 1.4**).

Figure 1. 4 Difference in probability of experiecing catastrophic health expenditures between households in poverty and households not in poverty with sick children



Note:

1. The observations numbers in the JSLC surveys vary by year (Most years have observation numbers between five thousand and eight thousand. For several years, the observation number is above fifteen thousand, such as 2008, and 2012). To increase the observation numbers involved in the generation of each data point in the figure above, we combined data from 1996 and 1997, 1998 and 1999, 2000 and 2001, 2001 and 2002, 2009 and 2010. Subjects under 18 years old in 2007 interviewed before May 28th, 2007 are combined to year 2006 to prevent losing observations. Sample weight is applied to all available years
2. Healthcare expenditure was considered to be catastrophic when the share of the household's out–of–pocket health expenditure was larger than 40% of the household's non–food consumption

Table 1. 3 ITS regressions on impact of user–fee–removal policy on out–of–pocket healthcare expenditure as a share of household's non–food consumption

	Aged less than 18–years			**Aged less than 5–years**		
	1) Overall	**2)** In poverty	**3)** Not in poverty	**4)** Overall	**5)** In poverty	**6)** Not in poverty
Trend	–0.003 (0.004)	–0.007 (0.007)	–0.002 (0.006)	–0.001 (0.007)	0.001 (0.015)	0 (0.008)
Level change after user–fee–removal policy (post)	–0.062‖ (0.023)	–0.121‖ (0.045)	–0.051 (0.031)	–0.071¶ (0.036)	–0.091 (0.085)	–0.057 (0.040)
Trend change after user–fee–removal policy (Post* trend)	0.006 (0.004)	0.013 (0.011)	0.004 (0.006)	0.005 (0.007)	0.008 (0.015)	0.002 (0.008)
Age	–0.001§ (0.000)	0.000 (0.001)	–0.001§ (0.000)	–0.003‖ (0.001)	–0.004¶ (0.002)	–0.003‖ (0.001)
Male	–0.004 (0.003)	–0.006 (0.009)	–0.004 (0.003)	–0.006 (0.007)	–0.001 (0.016)	–0.008 (0.008)
Head of the household	0.015 (0.066)	–0.073¶ (0.034)	0.100§ (0.008)			
Enrolled in private health insurance	–0.011¶ (0.006)	0.032 (0.026)	–0.021§ (0.006)	–0.017¶ (0.009)	–0.025‖ (0.010)	–0.022‖ (0.009)
Enrolled in public health insurance	–0.011 (0.008)	–0.015¶ (0.008)	–0.014 (0.011)	–0.007 (0.011)	–0.005 (0.014)	–0.015 (0.014)
Wealth (Poorest quintile is the reference group)†:						
Poorer	0.003 (0.004)			0.004 (0.005)		
Middle	0.008¶ (0.004)			0.01 (0.007)		
Richer	0.004 (0.009)			0.003 (0.012)		
Richest	–0.008 (0.006)			–0.009 (0.006)		
Household size	–0.006§ (0.001)	–0.002 (0.002)	–0.007§ (0.001)	–0.006§ (0.001)	–0.002 (0.002)	–0.008§ (0.002)
Place of residence ("rural" is the reference group):						
Urban	–0.005 (0.004)	–0.015 (0.012)	–0.003 (0.004)	–0.007 (0.005)	–0.016 (0.020)	–0.006 (0.004)
Town	–0.007§ (0.002)	–0.004 (0.004)	–0.008§ (0.003)	–0.004 (0.003)	0.005 (0.007)	–0.008‖ (0.003)
Education level of the head of the household ("no education" is the reference group)‡:						
Primary education (Grade 1–6)	–0.005 (0.006)	–0.023 (0.014)	0.000 (0.008)	–0.01 (0.013)	–0.045‖ (0.020)	0.006 (0.009)
Secondary education (Grade 7–13)	–0.010‖ (0.004)	–0.021* (0.011)	–0.007 (0.007)	–0.009 (0.005)	–0.024 (0.015)	–0.005 (0.009)
Higher education	–0.008* (0.004)	0.006 (0.012)	–0.013 (0.008)	–0.008 (0.006)	–0.011 (0.015)	–0.009 (0.009)
cons	0.128§ (0.022)	0.133‖ (0.056)	0.132§ (0.034)	0.132§ (0.040)	0.099 (0.085)	0.135‖ (0.049)
r^2	0.076	0.062	0.1	0.094	0.076	0.132
N	1921	439	1482	951	234	717

The design of JSLC is a two–stage stratified random sampling design, with the first stage a selection of Primary Sampling Units (PSUs), and the second stage a selection of dwellings. Standard errors are clustered at sampling region level, which is one level above the PSUs. Two PSUs were grouped into one sampling region. The robust standard errors are reported in parentheses. †We excluded the top 1% of individuals with the highest healthcare cost (outliers). ‡The education level of the household is obtained through the following approach: If the education level of the household head is available, we use it directly; if not available, we use the education level of the spouse of the household head instead; if still not available, we use the maximum education level of the household member instead; if still not available, we use the maximum education of the dwelling instead. §Represents significance at the 1% level. ‖Represents significance at the 5% level. ¶Represents significance at the 10% level. r^2 Represents the adjusted R square

1.3.3 Robustness check

To make sure that unobservable confounders do not drive our results, we conducted two robustness checks: First, we assume the removal of user fees in 2007 was targeted at adults aged more than 18–years. **Appendix Table 1.5** presents the regression results of the test. As expected, we can see that the coefficients on “post” and “post*trend” are neither with large magnitudes nor statistically significant, indicating that the policy change in 2007 did not have any notable impact on the adults aged more than 18–years in terms of healthcare utilization and financial burden. Second, we assume the user–fee–removal policy was implemented in May 28, 2006, instead of May 28, 2007. **Appendix Table 1.6, 1.7** and **1.8** present the results of using the alternative starting date. None of the coefficients on “post” and “post*trend” are with large magnitudes or statistically significant, suggesting the robustness of our findings.

1.4 Discussion

Figure 1.1 shows that the implementation of user–fee–removal policy in Jamaica led to increased children’s healthcare utilization immediately after the introduction of the policy and the utilization remained high in the medium–to–long–term. This finding is consistent with earlier studies elsewhere that elimination of user fees could effectively promote utilization because it removes financial barrier to access healthcare.(1–10)

The OLS regressions in **Appendix Table 1.1** suggest that healthcare utilization increased by 15.8 percentage points among children aged less than 18–years and 32.5 percentage points among children aged less than 5–years. In fact, a large proportion of children’s deaths are preventable and curable, for example, the 2005 MICS survey showed that 35% of Jamaican girls and 60% of the Jamaican boys with suspected pneumonia were not treated with potentially life–saving antibiotics.(31) Better healthcare access is an essential factor to save these lives.(32)

Figure 1.2, combined with the ITS results in **Table 1.2**, implies that the short–term and the medium–to–long–term results appear to have different equity impact: In the short–term (2007–2008), the utilization gap enlarged due to the faster increase in healthcare utilization among children not in poverty compared to children in poverty. One potential explanation for this observation is that wealthier households are better at receiving information about new policies and tend to be quicker in changing their behavior in the short–term. While in the medium– to long–term (after 2008), **Figure 1.2** further indicates that the utilization gap decreased rapidly as the utilization by children in poverty increased at a faster pace than non–poor between 2008 and 2012. This finding suggests that while conducting equity analysis, one should pay special attention to the study period, because various lengths of studies could produce different results.

We find that the user–fee–removal policy significantly reduced the share of out–of–pocket healthcare expenditure in households' non–food consumption by 6.2 percentage points among children aged less than 18–years and 7.1 percentage points among children aged less than 5–years. The children in poverty appear to benefit more than the children not in poverty, which indicates that the policy had a larger effect to relieve the financial burden of the poor. Our results are consistent with earlier studies undertaken elsewhere, demonstrating that user–fee exemptions reduce part of financial barriers for patients, and help improve access to health services.(33–36)

The study has four potential limitations. First, we cannot conclusively determine whether the increase in healthcare utilization was due to the release of unmet demand or moral hazard. When health services become free or inexpensive, people may tend to overuse them, leading to wastage of health resources. Whether this happened in the case of Jamaica and the extent to which it changed people's behavior is unclear. Second, due to the limited sample size, we are not able to conduct an analysis on the healthcare utilization among infants and can neither draw any conclusion on the link between the policy change and health outcomes. If more comprehensive data with larger sample size were available, more detailed analysis would be possible. Third, healthcare expenditure data is not collected yearly, but with a 4–week recall period. We adjusted the yearly non–food consumption to reflect the 4–week period. This method may generate biased estimates if the non–food consumption is not evenly divided over months or if children are more or less likely to be sick in the months the surveys were conducted. Fourth, although two sets of robustness checks were conducted, this study is still observational and could not completely rule out the possibility of confounders.

Notwithstanding these limitations, however, our results are in line with earlier studies undertaken elsewhere and strongly confirm the effectiveness of user–fee–removal policies in improving the equal access to healthcare for children by promoting the equitable utilization of health services and reducing the financial burden which households may confront.[1–10] An important implication of our results is that removing user fees is feasible and should be considered as part of a potential strategy to achieve UHC. Our results also suggest that the effects of policies may change over time. Hence, policymakers should take both short–term and the long–term effects into consideration when designing user–fee policies.

Appendix for Chapter 1

Appendix Table 1.1 ITS regression on the impact of user-fee-removal policy on healthcare utilization among children aged less-than 18-years old and children aged less than 5-years old, OLS regressions

	Under 18 years old			Under 5 years old		
	1) Overall	2) In poverty	3) Not in poverty	4) Overall	5) In poverty	6) Not in poverty
Trend	0.019*	-0.021	0.028*	0.033	0.003	0.034
	(0.010)	(0.026)	(0.014)	(0.022)	(0.047)	(0.022)
Post	0.158**	0.095	0.147**	0.325*	0.433	0.236
	(0.062)	(0.222)	(0.059)	(0.159)	(0.330)	(0.156)
Post*trend	-0.011	0.016	-0.016	-0.036	-0.032	-0.029
	(0.008)	(0.032)	(0.009)	(0.024)	(0.058)	(0.020)
Age	-0.010***	-0.005	-0.011***	-0.036***	-0.038**	-0.036***
	(0.001)	(0.010)	(0.002)	(0.006)	(0.012)	(0.006)
Male	-0.012	-0.023	-0.005	-0.01	-0.048	0.008
	(0.016)	(0.065)	(0.023)	(0.027)	(0.080)	(0.030)
Head of the household	0.057	-0.457**	0.430***			
	(0.248)	(0.172)	(0.050)			
Enrolled in private health insurance	0.104***	0.089	0.117**	0.023	-0.467***	0.074
	(0.032)	(0.127)	(0.042)	(0.038)	(0.134)	(0.055)
Enrolled in public health insurance	0.138	0.286***	0.109	0.174**	0.407***	0.099
	(0.081)	(0.057)	(0.097)	(0.074)	(0.035)	(0.111)
Wealth (Poorest quintile is the reference group)						
Poorer	0.041			0.065		
	(0.033)			(0.065)		
Middle	0.102***			0.122**		
	(0.023)			(0.051)		
Richer	0.143***			0.159**		
	(0.038)			(0.063)		
Richest	0.122**			0.172**		
	(0.041)			(0.068)		
Household size	-0.007	-0.011	-0.012	-0.006	-0.007	-0.012
	(0.004)	(0.014)	(0.007)	(0.009)	(0.021)	(0.010)
Place of residence ("Rural" is the reference group)						
Urban	0.037	0.003	0.054	0.023	0.069	0.027
	(0.046)	(0.099)	(0.051)	(0.048)	(0.116)	(0.049)
Town	0.012	-0.019	0.028	0.007	-0.097	0.051
	(0.055)	(0.072)	(0.051)	(0.062)	(0.132)	(0.056)
Education level of the head of the household ("No education" is the reference group)						
Primary education	-0.105***	-0.295***	-0.001	-0.126***	-0.363***	0.031
	(0.021)	(0.080)	(0.046)	(0.036)	(0.099)	(0.048)
Secondary education	-0.086**	-0.220***	-0.012	-0.056	-0.191**	0.02
	(0.039)	(0.040)	(0.064)	(0.040)	(0.065)	(0.060)
Higher education	-0.119**	-0.165*	-0.059	-0.082	-0.161**	-0.008
	(0.048)	(0.084)	(0.065)	(0.052)	(0.058)	(0.067)
cons	0.494***	0.868***	0.482***	0.461**	0.834**	0.495**
	(0.066)	(0.178)	(0.078)	(0.168)	(0.286)	(0.162)
N	1931	441	1488	959	237	722

Note:
1. We excluded all observations interviewed within four weeks after the interview date to make sure there is no confusion over whether the illnesses happened before or after the policy took place.

Appendix Table 1.1 (Continued) ITS regression on the impact of user-fee-removal policy on healthcare utilization among children aged less-than 18-years old and children aged less than 5-years old, OLS regressions

2. The design of JSLC is a two-stage stratified random sampling design, with the first stage a selection of Primary Sampling Units (PSUs), and the second stage a selection of dwellings. Standard errors are clustered at sampling region level, which is one level above the PSUs. Two PSUs were grouped into one sampling region. The robust standard errors are reported in parentheses.
3. The education level of the household is obtained through the following approach: If the education level of the household head is available, we use it directly; if not available, we use the education level of the spouse of the household head instead; if still not available, we use the maximum education level of the household member instead; if still not available, we use the maximum education of the dwelling instead.
4. ***, **, * represents significance at the 1%, 5%, and 10% level respectively.
5. SEs are presented in the parenthesis.

Appendix Table 1.2 ITS regression on the impact of user-fee-removal policy on healthcare utilization among children aged less than 18-years old, year 1996-2012

	OLS			Logit		
	1) Overall	2) In poverty	3) Not in poverty	4) Overall	5) In poverty	6) Not in poverty
Trend	-0.008	-0.018	0.012	-0.033	-0.075	0.051
	(0.010)	(0.028)	(0.010)	(0.061)	(0.117)	(0.044)
Level change after user-fee-removal policy (Post)	0.079*	0.058	0.158***	0.358	0.242	0.692***
	(0.048)	(0.107)	(0.037)	(0.373)	(0.445)	(0.161)
Trend change after user-fee-removal policy (Post*trend)	0.007	0.018	-0.014	0.027	0.072	-0.058
	(0.010)	(0.028)	(0.010)	(0.062)	(0.116)	(0.043)
Age	-0.011***	-0.007	-0.010***	-0.045***	-0.029	-0.042***
	(0.002)	(0.006)	(0.001)	(0.005)	(0.024)	(0.007)
Male	0.009	0.03	0.005	0.039	0.123	0.022
	(0.015)	(0.047)	(0.010)	(0.050)	(0.190)	(0.044)
Head of the household	0.21	-0.333***	0.462***	0.929*	0	0
	(0.248)	(0.059)	(0.065)	(0.478)	(.)	(.)
Enrolled in private health insurance	0.077***	0.14	0.078**	0.371**	0.614	0.360**
	(0.027)	(0.094)	(0.030)	(0.155)	(0.433)	(0.151)
Enrolled in public health insurance	-0.021	-0.02	-0.019	-0.084	-0.083	-0.069
	(0.023)	(0.047)	(0.027)	(0.086)	(0.191)	(0.115)
Wealth (Poorest quintile is the reference group)						
Poorer	-0.01			-0.04		
	(0.024)			(0.116)		
Middle	0.071***			0.295***		
	(0.024)			(0.070)		
Richer	0.122***			0.522***		
	(0.026)			(0.187)		
Richest	0.120***			0.516***		
	(0.029)			(0.132)		
Household size	0.001	0.004	-0.009***	0.004	0.015	-0.040***
	(0.003)	(0.004)	(0.003)	(0.012)	(0.017)	(0.012)
Place of residence ("Rural" is the reference group)						
Urban	0.025	0.032	0.043	0.109	0.135	0.187
	(0.019)	(0.087)	(0.030)	(0.149)	(0.361)	(0.133)
Town	-0.01	0.007	0.015	-0.042	0.027	0.063
	(0.022)	(0.053)	(0.033)	(0.161)	(0.217)	(0.137)
Education level of the head of the household ("No education" is the reference group)						
Primary education	-0.029	-0.112**	-0.034	-0.116	-0.457**	-0.137
	(0.029)	(0.051)	(0.035)	(0.119)	(0.214)	(0.151)
Secondary education	-0.034	-0.075	-0.044	-0.134	-0.31	-0.176
	(0.029)	(0.053)	(0.035)	(0.144)	(0.222)	(0.151)
Higher education	-0.042	0.004	-0.036	-0.167	0.022	-0.141
	(0.033)	(0.107)	(0.033)	(0.115)	(0.447)	(0.141)
cons	0.623***	0.595**	0.662***	0.491	0.384	0.662***
	(0.064)	(0.208)	(0.030)	(0.380)	(0.863)	(0.128)
r2	0.043	0.032	0.037			
N	3920	881	3545	3920	880	3543

Note:

1. We excluded all observations interviewed within four weeks after the interview date to make sure there is no confusion over whether the illnesses happened before or after the policy took place.

Appendix Table 1.2 (continued) ITS regression on the impact of user-fee-removal policy on healthcare utilization among children aged less than 18-years old, year 1996-2012

2. The design of JSLC is a two-stage stratified random sampling design, with the first stage a selection of Primary Sampling Units (PSUs), and the second stage a selection of dwellings. Standard errors are clustered at sampling region level, which is one level above the PSUs. Two PSUs were grouped into one sampling region. The robust standard errors are reported in parentheses.
3. The education level of the household is obtained through the following approach: If the education level of the household head is available, we use it directly; if not available, we use the education level of the spouse of the household head instead; if still not available, we use the maximum education level of the household member instead; if still not available, we use the maximum education of the dwelling instead.
4. ***, **, * represents significance at the 1%, 5%, and 10% level respectively.
5. SEs are presented in the parenthesis.

Appendix Table 1.3 ITS regression on the impact of user-fee-removal policy on healthcare utilization among children aged less than 5-years old, year 1996-2012

	OLS			Logit		
	1) Overall	2) In poverty	3) Not in poverty	4) Overall	5) In poverty	6) Not in poverty
Trend	0.022	0.021	0.016	0.112	0.099	0.081
	(0.023)	(0.031)	(0.014)	(0.111)	(0.137)	(0.063)
Level change after user-fee-removal policy (Post)	0.256	0.219	0.226*	1.246	0.966	1.118*
	(0.171)	(0.262)	(0.113)	(0.866)	(1.130)	(0.608)
Trend change after user-fee-removal policy (Post*trend)	-0.026	-0.023	-0.02	-0.131	-0.105	-0.103
	(0.026)	(0.038)	(0.017)	(0.130)	(0.164)	(0.084)
Age	-0.041***	-0.053**	-0.031***	-0.189***	-0.230***	-0.145***
	(0.009)	(0.018)	(0.007)	(0.044)	(0.083)	(0.035)
Male	0.012	-0.063	0.023	0.058	-0.28	0.107
	(0.023)	(0.056)	(0.024)	(0.109)	(0.232)	(0.110)
Enrolled in private health insurance	0.072	-0.071	0.106**	0.391*	-0.307	0.552**
	(0.044)	(0.060)	(0.047)	(0.236)	(0.251)	(0.264)
Enrolled in public health insurance	0.097**	0.075	0.056	0.486**	0.337	0.295
	(0.043)	(0.129)	(0.049)	(0.227)	(0.550)	(0.247)
Wealth (Poorest quintile is the reference group)						
Poorer	0.037			0.161		
	(0.040)			(0.172)		
Middle	0.106**			0.474***		
	(0.037)			(0.164)		
Richer	0.165***			0.767***		
	(0.053)			(0.245)		
Richest	0.140**			0.657**		
	(0.061)			(0.324)		
Household size	0.003	-0.004	-0.003	0.013	-0.018	-0.013
	(0.005)	(0.012)	(0.006)	(0.023)	(0.054)	(0.025)
Place of residence ("Rural" is the reference group)						
Urban	0.056	0.028	0.071*	0.273	0.112	0.342*
	(0.042)	(0.096)	(0.037)	(0.204)	(0.415)	(0.190)
Town	-0.008	-0.091	0.041	-0.039	-0.395	0.184
	(0.047)	(0.089)	(0.043)	(0.219)	(0.389)	(0.198)
Education level of the head of the household ("No education" is the reference group)						
Primary education	-0.168***	-0.340***	-0.090**	-0.770***	-1.512***	-0.396**
	(0.040)	(0.089)	(0.040)	(0.191)	(0.426)	(0.173)
Secondary education	-0.079	-0.189***	-0.050**	-0.375	-0.852***	-0.226***
	(0.045)	(0.053)	(0.020)	(0.229)	(0.246)	(0.088)
Higher education	-0.091*	-0.141**	-0.043	-0.435*	-0.642**	-0.201
	(0.045)	(0.063)	(0.049)	(0.229)	(0.279)	(0.227)
cons	0.541***	0.751***	0.621***	0.109	1.079	0.458
	(0.140)	(0.190)	(0.067)	(0.672)	(0.833)	(0.323)
r2	0.061	0.082	0.041			
N	1901	424	1767	1901	424	1767

Note:
1. We excluded all observations interviewed within four weeks after the interview date to make sure there is no confusion over whether the illnesses happened before or after the policy took place.
2. The design of JSLC is a two-stage stratified random sampling design, with the first stage a selection of Primary Sampling Units (PSUs), and the second stage a selection of dwellings. Standard errors are clustered at sampling region level, which is one level above the PSUs. Two PSUs were grouped into one sampling region. The robust standard errors are reported in parentheses.

Appendix Table 1.3 (continued) ITS regression on the impact of user-fee-removal policy on healthcare utilization among children aged less than 5-years old, year 1996-2012

3. The education level of the household is obtained through the following approach: If the education level of the household head is available, we use it directly; if not available, we use the education level of the spouse of the household head instead; if still not available, we use the maximum education level of the household member instead; if still not available, we use the maximum education of the dwelling instead.
4. ***, **, * represents significance at the 1%, 5%, and 10% level respectively.
5. SEs are presented in the parenthesis.

Appendix Table 1.4 ITS regression on the impact of user-fee-removal policy on out-of-pocket healthcare expenditure as a share of the household's non-food consumption, year 1996-2012

	Under 18 years old			Under 5 years old		
	1)	2)	3)	4)	5)	6)
	Overall	In poverty	Not in poverty	Overall	In poverty	Not in poverty
Trend	-0.002	-0.006	0.001	-0.001	-0.003	0.002
	(0.003)	(0.005)	(0.002)	(0.004)	(0.005)	(0.002)
Level change after user-fee-removal policy (Post)	-0.056***	-0.118***	-0.031	-0.070***	-0.116***	-0.043**
	(0.014)	(0.035)	(0.020)	(0.018)	(0.031)	(0.015)
Trend change after user-fee-removal policy (Post*trend)	0.004	0.014**	0.000	0.005	0.012**	0.000
	(0.003)	(0.005)	(0.003)	(0.004)	(0.005)	(0.003)
Age	-0.001***	-0.001	-0.001***	-0.002	-0.006***	-0.001
	0.000	(0.001)	0.000	(0.002)	(0.002)	(0.001)
Male	-0.001	0.002	0.000	-0.002	0.004	-0.001
	(0.003)	(0.009)	(0.003)	(0.006)	(0.010)	(0.005)
Head of the household	0.044	-0.064**	0.103***			
	(0.033)	(0.026)	(0.006)			
Enrolled in private health insurance	-0.008	0.027	-0.020***	-0.011	-0.029**	-0.023**
	(0.005)	(0.028)	(0.005)	(0.010)	(0.010)	(0.008)
Enrolled in public health insurance	-0.008	-0.014	-0.005	-0.007	0.004	-0.005
	(0.005)	(0.016)	(0.004)	(0.008)	(0.014)	(0.008)
Wealth (Poorest quintile is the reference group)						
Poorer	-0.004			-0.006		
	(0.006)			(0.008)		
Middle	0.001			0.004		
	(0.008)			(0.009)		
Richer	-0.003			-0.006		
	(0.009)			(0.013)		
Richest	-0.021**			-0.028**		
	(0.009)			(0.011)		
Household size	-0.005***	-0.003	-0.006***	-0.006***	-0.003*	-0.007***
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Place of residence ("Rural" is the reference group)						
Urban	-0.002	-0.01	-0.005	0.002	-0.001	-0.002
	(0.003)	(0.016)	(0.003)	(0.003)	(0.024)	(0.005)
Town	-0.009***	-0.001	-0.007**	-0.005	0.000	-0.002
	(0.002)	(0.008)	(0.003)	(0.003)	(0.006)	(0.007)
Education level of the head of the household ("No education" is the reference group)						
Primary education	-0.01	-0.021	-0.01	-0.017	-0.035*	-0.012
	(0.007)	(0.012)	(0.006)	(0.012)	(0.016)	(0.009)
Secondary education	-0.014**	-0.022**	-0.012**	-0.014*	-0.023	-0.013
	(0.005)	(0.009)	(0.005)	(0.006)	(0.014)	(0.009)
Higher education	-0.012**	0.004	-0.014	-0.012*	-0.009	-0.013
	(0.005)	(0.011)	(0.008)	(0.007)	(0.013)	(0.012)
cons	0.132***	0.131**	0.115***	0.141***	0.127**	0.128***
	(0.012)	(0.046)	(0.007)	(0.020)	(0.043)	(0.015)
r2	0.051	0.066	0.052	0.07	0.076	0.071
N	3873	869	3500	1876	461	1699

Note:
1. We excluded all observations interviewed within four weeks after the interview date to make sure there is no confusion over whether the illnesses happened before or after the policy took place.

Appendix Table 1.4 (continued) ITS regression on the impact of user-fee-removal policy on out-of-pocket healthcare expenditure as a share of the household's non-food consumption, year 1996-2012

2. The design of JSLC is a two-stage stratified random sampling design, with the first stage a selection of Primary Sampling Units (PSUs), and the second stage a selection of dwellings. Standard errors are clustered at sampling region level, which is one level above the PSUs. Two PSUs were grouped into one sampling region. The robust standard errors are reported in parentheses.
3. The education level of the household is obtained through the following approach: If the education level of the household head is available, we use it directly; if not available, we use the education level of the spouse of the household head instead; if still not available, we use the maximum education level of the household member instead; if still not available, we use the maximum education of the dwelling instead.
4. We dropped 1% of individuals with the highest healthcare cost (outliers).
5. ***, **, * represents significance at the 1%, 5%, and 10% level respectively.
6. SEs are presented in the parenthesis.

Appendix Table 1.5 Falsification tests on the impact of user-fee-removal policy on healthcare utilization and the households' financial burden, assuming the user-fee-removal policy targeted at adults over 18, OLS regressions

	Y=whether the children visit a health practitioner if fell ill in the past 4 weeks			Y=the children's out-of-pocket healthcare expenditure as a share of household's non-food consumption		
	1)	2)	3)	4)	5)	6)
	Overall	In poverty	Not in poverty	Overall	In poverty	Not in poverty
Trend	0.016	0.034	0.011	0	0.007	-0.001
	(0.010)	(0.034)	(0.011)	(0.002)	(0.012)	(0.002)
Level change after user-fee-removal policy (Post)	0.015	0.048	-0.013	-0.009	0.03	-0.02
	(0.049)	(0.185)	(0.069)	(0.014)	(0.047)	(0.016)
Trend change after user-fee-removal policy (Post*trend)	-0.002	-0.012	0.003	-0.002	-0.009	0
	(0.009)	(0.032)	(0.012)	(0.002)	(0.011)	(0.002)
Age	0.001	0	0.001	0.001***	0	0.001***
	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
Male	-0.051**	-0.024	-0.053**	-0.005*	0.001	-0.006
	(0.023)	(0.046)	(0.021)	(0.002)	(0.011)	(0.004)
Head of the household	0.008	0.008	0.007	0.005**	-0.011	0.007***
	(0.017)	(0.059)	(0.013)	(0.002)	(0.014)	(0.002)
Enrolled in private health insurance	0.112***	0.089	0.123***	-0.010**	0.022	-0.010**
	(0.019)	(0.064)	(0.023)	(0.003)	(0.014)	(0.003)
Enrolled in public health insurance	0.044	0.058	0.046	-0.01	-0.001	-0.011
	(0.029)	(0.077)	(0.032)	(0.006)	(0.019)	(0.008)
Wealth (Poorest quintile is the reference group)						
Poorer	0.041**			0.015**		
	(0.014)			(0.006)		
Middle	0.075***			0.015**		
	(0.010)			(0.006)		
Richer	0.094***			0.018***		
	(0.014)			(0.004)		
Richest	0.124***			0.022***		
	(0.016)			(0.003)		
Household size	0.015***	0.020**	0.007**	-0.003***	0.003**	-0.006***
	(0.003)	(0.006)	(0.003)	(0.001)	(0.001)	(0.001)
Place of residence ("Rural" is the reference group)						
Urban	-0.012	0.042	-0.007	-0.01	-0.007	-0.009
	(0.027)	(0.052)	(0.025)	(0.006)	(0.016)	(0.005)
Town	-0.008	0.091	-0.012	-0.011*	-0.008	-0.01
	(0.024)	(0.051)	(0.027)	(0.006)	(0.009)	(0.006)
Education level of the head of the household ("No education" is the reference group)						
Primary education	0.041	0.056	0.043	0.007	-0.003	0.008
	(0.048)	(0.124)	(0.040)	(0.013)	(0.023)	(0.012)
Secondary education	0.011	-0.01	0.022	0.013	0.016	0.011
	(0.046)	(0.128)	(0.047)	(0.013)	(0.021)	(0.012)
Higher education	-0.059	-0.041	-0.038	-0.001	0.009	0
	(0.059)	(0.076)	(0.054)	(0.013)	(0.033)	(0.013)
cons	0.336***	0.153	0.481***	0.055***	-0.016	0.092***
	(0.093)	(0.191)	(0.081)	(0.015)	(0.050)	(0.014)
r2	0.057	0.086	0.049	0.065	0.034	0.081
N	4165	595	3570	4165	595	3570

Appendix Table 1.5 (continued) Falsification tests on the impact of user-fee-removal policy on healthcare utilization and the households' financial burden, assuming the user-fee-removal policy targeted at adults over 18, OLS regressions

Note:

1. We excluded all observations interviewed within four weeks after the interview date to make sure there is no confusion over whether the illnesses happened before or after the policy took place.
2. The design of JSLC is a two-stage stratified random sampling design, with the first stage a selection of Primary Sampling Units (PSUs), and the second stage a selection of dwellings. Standard errors are clustered at sampling region level, which is one level above the PSUs. Two PSUs were grouped into one sampling region. The robust standard errors are reported in parentheses.
3. The education level of the household is obtained through the following approach: If the education level of the household head is available, we use it directly; if not available, we use the education level of the spouse of the household head instead; if still not available, we use the maximum education level of the household member instead; if still not available, we use the maximum education of the dwelling instead.
4. ***, **, * represents significance at the 1%, 5%, and 10% level respectively.
5. SEs are presented in the parenthesis.

Appendix Table 1.6 Falsification tests on the impact of user-fee-removal policy on healthcare utilization among children aged less than 18-years, assuming the user-fee-removal policy was implemented on May 28th, 2006

	OLS			Logit		
	1)	2)	3)	4)	5)	6)
	Overall	In poverty	Not in poverty	Overall	In poverty	Not in poverty
Trend	-0.006	-0.006	-0.006	-0.02	-0.021	-0.023
	(0.049)	(0.060)	(0.050)	(0.211)	(0.286)	(0.209)
Level change after user-fee-removal policy (Post)	-0.014	-0.067	-0.033	-0.06	-0.223	-0.166
	(0.197)	(0.269)	(0.215)	(0.861)	(1.295)	(0.934)
Trend change after user-fee-removal policy (Post*trend)	0.021	0.03	0.022	0.091	0.12	0.096
	(0.050)	(0.053)	(0.053)	(0.217)	(0.259)	(0.227)
Age	-0.009***	-0.004	-0.009***	-0.042***	-0.02	-0.042***
	(0.002)	(0.008)	(0.002)	(0.008)	(0.036)	(0.009)
Male	-0.021	-0.081	-0.002	-0.095	-0.359	-0.006
	(0.020)	(0.054)	(0.028)	(0.093)	(0.234)	(0.128)
Head of the household	-0.157	0	-0.196	-0.684	0	-0.82
	(0.233)	(.)	(0.250)	(1.146)	(.)	(1.206)
Enrolled in private health insurance	0.109***	0.148	0.120***	0.553***	0.624	0.605***
	(0.028)	(0.119)	(0.037)	(0.154)	(0.536)	(0.200)
Enrolled in public health insurance	0.138	-0.048	0.152	0.655	-0.247	0.737
	(0.090)	(0.342)	(0.086)	(0.487)	(1.375)	(0.483)
Wealth (Poorest quintile is the reference group)						
Poorer	0.035			0.148		
	(0.037)			(0.157)		
Middle	0.082*			0.356**		
	(0.038)			(0.164)		
Richer	0.129**			0.579***		
	(0.047)			(0.217)		
Richest	0.099**			0.442**		
	(0.042)			(0.196)		
Household size	-0.009**	-0.014	-0.012	-0.039**	-0.064	-0.053*
	(0.004)	(0.012)	(0.007)	(0.017)	(0.048)	(0.031)
Place of residence ("Rural" is the reference group)						
Urban	0.029	-0.012	0.048	0.131	-0.045	0.227
	(0.044)	(0.086)	(0.048)	(0.205)	(0.367)	(0.232)
Town	0.022	0.034	0.03	0.102	0.16	0.136
	(0.064)	(0.081)	(0.054)	(0.287)	(0.340)	(0.243)
Education level of the head of the household ("No education" is the reference group)						
Primary education	-0.064	-0.319***	0.041	-0.297	-1.577***	0.197
	(0.037)	(0.072)	(0.055)	(0.183)	(0.203)	(0.244)
Secondary education	-0.057	-0.279***	0.037	-0.268	-1.404***	0.18
	(0.036)	(0.037)	(0.049)	(0.174)	(0.290)	(0.221)
Higher education	-0.083**	-0.23	0.002	-0.392***	-1.198	0.015
	(0.031)	(0.131)	(0.066)	(0.151)	(0.735)	(0.304)
cons	0.559**	0.779**	0.560**	0.233	1.375	0.204
	(0.194)	(0.295)	(0.218)	(0.828)	(1.283)	(0.910)
r2	0.061	0.088	0.049			
N	1960	332	1628	1952	331	1621

Note:

1. We excluded all observations interviewed within four weeks after May 28th, 2006, to make sure there is no confusion over whether the illnesses happened before or after the policy took place.

Appendix Table 1.6 (continued) Falsification tests on the impact of user-fee-removal policy on healthcare utilization among children aged less than 18-years, assuming the user-fee-removal policy was implemented on May 28th, 2006

2. The design of JSLC is a two-stage stratified random sampling design, with the first stage a selection of Primary Sampling Units (PSUs), and the second stage a selection of dwellings. Standard errors are clustered at sampling region level, which is one level above the PSUs. Two PSUs were grouped into one sampling region. The robust standard errors are reported in parentheses.
3. The education level of the household is obtained through the following approach: If the education level of the household head is available, we use it directly; if not available, we use the education level of the spouse of the household head instead; if still not available, we use the maximum education level of the household member instead; if still not available, we use the maximum education of the dwelling instead.
4. ***, **, * represents significance at the 1%, 5%, and 10% level respectively.
5. SEs are presented in the parenthesis.

Appendix Table 1.7 Falsification tests on the impact of user-fee-removal policy on healthcare utilization among children aged less than 5-years, assuming the user-fee-removal policy was implemented on May 28th, 2006

	OLS			Logit		
	1) Overall	2) In poverty	3) Not in poverty	4) Overall	5) In poverty	6) Not in poverty
Trend	0.007	0.054	-0.015	0.036	0.287	-0.059
	(0.064)	(0.085)	(0.091)	(0.267)	(0.362)	(0.376)
Level change after user-fee-removal policy (Post)	0.061	0.016	-0.028	0.294	0.22	-0.114
	(0.212)	(0.381)	(0.325)	(0.879)	(1.638)	(1.338)
Trend change after user-fee-removal policy (Post*trend)	0.004	-0.03	0.026	0.014	-0.17	0.113
	(0.059)	(0.084)	(0.087)	(0.246)	(0.355)	(0.360)
Age	-0.040***	-0.096***	-0.026**	-0.188***	-0.439***	-0.126***
	(0.007)	(0.027)	(0.009)	(0.038)	(0.115)	(0.042)
Male	-0.011	-0.087	0.014	-0.046	-0.434	0.075
	(0.031)	(0.055)	(0.042)	(0.145)	(0.275)	(0.197)
Enrolled in private health insurance	0.049	-0.329**	0.082	0.248	-1.584***	0.424
	(0.040)	(0.120)	(0.051)	(0.203)	(0.563)	(0.271)
Enrolled in public health insurance	0.139	0.165	0.144	0.702	0.769	0.73
	(0.091)	(0.204)	(0.093)	(0.516)	(0.843)	(0.539)
Wealth (Poorest quintile is the reference group)						
Poorer	0.11			0.469*		
	(0.063)			(0.276)		
Middle	0.148**			0.654**		
	(0.060)			(0.275)		
Richer	0.183**			0.835***		
	(0.063)			(0.302)		
Richest	0.183**			0.844**		
	(0.080)			(0.414)		
Household size	-0.005	-0.013	-0.009	-0.022	-0.058	-0.041
	(0.007)	(0.018)	(0.007)	(0.031)	(0.082)	(0.034)
Place of residence ("Rural" is the reference group)						
Urban	0.029	0.051	0.046	0.132	0.26	0.223
	(0.047)	(0.085)	(0.047)	(0.220)	(0.361)	(0.231)
Town	0.056	-0.032	0.078	0.271	-0.155	0.383
	(0.080)	(0.110)	(0.071)	(0.372)	(0.509)	(0.343)
Education level of the head of the household ("No education" is the reference group)						
Primary education	-0.016	-0.281**	0.082	-0.063	-1.390**	0.393
	(0.069)	(0.119)	(0.054)	(0.311)	(0.568)	(0.241)
Secondary education	0.01	-0.215**	0.087	0.055	-1.055**	0.417*
	(0.061)	(0.083)	(0.049)	(0.287)	(0.432)	(0.219)
Higher education	0.004	-0.133	0.074	0.023	-0.69	0.352
	(0.068)	(0.203)	(0.060)	(0.319)	(0.965)	(0.276)
cons	0.444	0.859*	0.548	-0.299	1.562	0.117
	(0.278)	(0.438)	(0.393)	(1.152)	(1.845)	(1.637)
r2	0.072	0.173	0.047			
N	960	169	791	959	169	790

Note:
1. We excluded all observations interviewed within four weeks after May 28th, 2006, to make sure there is no confusion over whether the illnesses happened before or after the policy took place.
2. The design of JSLC is a two-stage stratified random sampling design, with the first stage a selection of Primary Sampling Units (PSUs), and the second stage a selection of dwellings. Standard errors are clustered at sampling region level, which is one level above the PSUs. Two PSUs were grouped into one sampling region. The robust standard errors are reported in parentheses.

Appendix Table 1.7 (continued) Falsification tests on the impact of user-fee-removal policy on healthcare utilization among children aged less than 5-years, assuming the user-fee-removal policy was implemented on May 28th, 2006

3. The education level of the household is obtained through the following approach: If the education level of the household head is available, we use it directly; if not available, we use the education level of the spouse of the household head instead; if still not available, we use the maximum education level of the household member instead; if still not available, we use the maximum education of the dwelling instead.
4. ***, **, * represents significance at the 1%, 5%, and 10% level respectively.
5. SEs are presented in the parenthesis.

Appendix Table 1.8 Falsification tests on the impact of user-fee-removal policy on out-of-pocket healthcare expenditure as a share of the household's non-food consumption, assuming the user-fee-removal policy was implemented on May 28th, 2006

	Under 18			Under 5		
	1)	2)	3)	4)	5)	6)
	Overall	In poverty	Not in poverty	Overall	In poverty	Not in poverty
Trend	-0.001	0.003	-0.005	0.009	0.035	-0.001
	(0.010)	(0.014)	(0.010)	(0.010)	(0.022)	(0.015)
Level change after user-fee-	-0.028	-0.042	-0.039	0.004	0.071	-0.027
removal policy (Post)	(0.048)	(0.081)	(0.046)	(0.040)	(0.120)	(0.058)
Trend change after user-fee-	0.001	0.001	0.004	-0.009	-0.029	0
removal policy (Post*trend)	(0.011)	(0.016)	(0.010)	(0.010)	(0.023)	(0.015)
Age	-0.001**	-0.001	-0.001**	-0.003*	-0.002	-0.003**
	0.000	(0.001)	0.000	(0.002)	(0.005)	(0.001)
Male	-0.004	-0.017	-0.002	-0.007	-0.023	-0.004
	(0.004)	(0.012)	(0.005)	(0.008)	(0.018)	(0.010)
Head of the household	0.012	0	0.003	0	0	0
	(0.064)	(.)	(0.063)	(.)	(.)	(.)
Enrolled in private health	-0.01	0.042	-0.018**	-0.014	-0.046***	-0.016
insurance	(0.007)	(0.024)	(0.008)	(0.011)	(0.010)	(0.011)
Enrolled in public health	-0.01	-0.055**	-0.009	-0.008	-0.044**	-0.007
insurance	(0.007)	(0.019)	(0.007)	(0.013)	(0.017)	(0.013)
Wealth (Poorest quintile is the reference group)						
Poorer	-0.002			0		
	(0.006)			(0.005)		
Middle	0.007			0.01		
	(0.004)			(0.008)		
Richer	0.001			0.002		
	(0.011)			(0.012)		
Richest	-0.012			-0.01		
	(0.007)			(0.006)		
Household size	-0.006***	-0.002	-0.007***	-0.005***	0	-0.007***
	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)
Place of residence ("Rural" is the reference group)						
Urban	-0.008*	-0.013	-0.008*	-0.006	0	-0.010**
	(0.004)	(0.012)	(0.004)	(0.005)	(0.020)	(0.004)
Town	-0.006***	-0.007	-0.007***	0.002	-0.009	0.001
	(0.002)	(0.007)	(0.002)	(0.003)	(0.008)	(0.003)
Education level of the head of the household ("No education" is the reference group)						
Primary education	-0.004	-0.013	0	-0.004	-0.041**	0.006
	(0.009)	(0.018)	(0.011)	(0.015)	(0.017)	(0.013)
Secondary education	-0.009	-0.022*	-0.005	-0.007	-0.024**	-0.001
	(0.006)	(0.012)	(0.009)	(0.007)	(0.010)	(0.009)
Higher education	-0.007	0.007	-0.008	-0.006	-0.017	-0.001
	(0.006)	(0.007)	(0.009)	(0.008)	(0.010)	(0.010)
cons	0.119**	0.085	0.138***	0.08	-0.042	0.127*
	(0.047)	(0.071)	(0.044)	(0.049)	(0.133)	(0.066)
r2	0.069	0.084	0.079	0.076	0.093	0.093
N	1938	343	1595	1931	342	1589

Note:
1. We excluded all observations interviewed within four weeks after May 28th, 2006, to make sure there is no confusion over whether the illnesses happened before or after the policy took place.

Appendix Table 1.8 (continued) Falsification tests on the impact of user-fee-removal policy on out-of-pocket healthcare expenditure as a share of the household's non-food consumption, assuming the user-fee-removal policy was implemented on May 28th, 2006

2. The design of JSLC is a two-stage stratified random sampling design, with the first stage a selection of Primary Sampling Units (PSUs), and the second stage a selection of dwellings. Standard errors are clustered at sampling region level, which is one level above the PSUs. Two PSUs were grouped into one sampling region. The robust standard errors are reported in parentheses. The education level of the household is obtained through the following approach: If the education level of the household head is available, we use it directly; if not available, we use the education level of the spouse of the household head instead; if still not available, we use the maximum education level of the household member instead; if still not available, we use the maximum education of the dwelling instead.
3. ***, **, * represents significance at the 1%, 5%, and 10% level respectively.
4. SEs are presented in the parenthesis.

Chapter 2

Distributional impact of a nutritional package targeting children aged 6-36 months in China: findings from an extended cost-effectiveness analysis

Abstract

Background

Despite rapid economic development, child stunting remains a persistent problem in China, where stunting prevalence varies greatly across provinces and socioeconomic groups. We modeled the distributional impact of Yingyangbao (YYB), a nutritional intervention package included in the national nutrition strategy that targets young children, across geographical regions and socioeconomic groups in China.

Methods

We used data from China's Family Panel Studies and built on extended cost-effectiveness analysis methods to model the costs of a potential 12-month YYB program targeting Chinese children aged 6-36 months and the associated number of stunting cases averted, across 25 provinces and two socioeconomic groups – those living below or above the international poverty line of $5.50 per day (equaling to ¥35.5 RMB, 2011 Purchasing Power Parity).

Findings

We showed that 75% coverage of YYB could avert about 1.9 million stunting cases among 6-36 month-olds, 67% of those would accrue among children living below the poverty line, at a total cost of ¥5.4-6.2 billion depending on the type of YYB delivery. Given the large heterogeneities across Chinese provinces, the cost per stunting case averted would range from a low ¥800 (Chongqing province) to a high ¥23,400 (Jilin).

Discussion

YYB could be a pro-poor nutritional intervention package that brings substantial health benefits to poor and marginalized Chinese children, but with large variations in value for money across provinces. This analysis points to the need for prioritization across provinces and a targeted approach for YYB rollout in China.

2.1 Introduction

As of 2015, China was home to 86 million children under 5 years of age, accounting for 13% of the world's under-5 population.(37) Despite rapid economic growth, China is still one of the countries with large numbers of stunted children (height-for-age z score less than 2 standard deviations [SD]) globally: it is estimated that 12% of under-five years old Chinese children were stunted in 2016, equaling to about 10 million children.(38)

Large disparities in child stunting rates exist within China, with a prevalence ranging from 4% in urban areas to 16% in rural areas, and from being almost absent in rich provinces and cities like Beijing, Tianjin, and Shanghai, to being as prevalent as 29% in poor provinces and cities like Sichuan and Gansu (38). Stunting occurs when a child is subjected to malnutrition early on in her/his life. There is evidence showing that stunting in under-five children could lead to impaired cognitive development, affecting educational performance and long-term economic productivity.(39–41) Often, children living in poor families and regions of China are more likely to be stuck in a cycle of poverty as stunting can be both a cause and consequence of poverty.(42)

To improve nutritional status among Chinese children, the Yingyangbao (YYB) nutritional package was introduced to China's poor rural areas in 2001.(43) YYB is a nutrient-dense food supplement targeting infants and young children, usually aged 6-36 months. The base of YYB is constituted of full fat powder and multiple micronutrient powders, including calcium, iron, zinc, and vitamins; folic acid, omega 3, omega 6, thiamin, or riboflavin are also sometimes added. The exact composition of YYB varies slightly depending on the manufacturing companies.(43–46)

Compared to micronutrient and other complementary feeding supplements, such as sprinkles, crushable tablets, and fat-based products, YYB is composed of soybean powder that provides both calories (usually around 50Kcal per pack) and protein (3g per pack) in addition to various micronutrients. (43–46)

The YYB program was first piloted and launched in 2001 in five counties of Gansu province and targeted 4-12 month-olds.(47) Since, it gradually expanded to other rural areas and regions affected by natural disasters. In 2011, the Chinese government invested ¥100 million (USD16 million) for the YYB program covering 300,000 children in 100 counties across 10 provinces.(48) This investment further expanded to ¥500 million (USD81 million) covering 1.4 million children across 21 provinces. In 2017, the Chinese government issued a national nutrition strategy (for the years 2017-2030) that clearly prioritized the promotion of nutritional status of children in their first 1,000 days (49); and YYB was then proposed as one key intervention for rural and poor regions. (49)

A number of previous studies have demonstrated the effectiveness of YYB on improving children's nutritional status. A meta-analysis adopted five high-quality studies (interventions were randomized either at county level or at individual level) with low between-study heterogeneity, and showed that YYB was associated with an average of 0.28 SD increase in height-for-age z score and 32% decrease in stunting prevalence.(50) However, little work has assessed the cost-effectiveness of YYB delivery and its potential distributional impact across China's provinces and socioeconomic groups. In this study, we employ extended cost-effectiveness analysis (ECEA) methods (51,52) to study the distributional impact of YYB rollout in China.

2.2 Methods

We examined the distributional impact of YYB across provinces and two socioeconomic groups in China, while developing a simple epidemiological-cost model capturing the variations in delivery costs across Chinese provinces that would depend on different types of YYB delivery utilized and transportation availability.

2.2.1 Setting

Our analysis focused on rural Chinese children aged 6-36 months because YYB usually targets this age group and stunting prevalence was about four times as high in rural areas (12%) as in urban areas (3%) among this age group.(38) We examined this question within individual provinces and across two wealth groups: those living under the World Bank's international poverty line ($5.5 per day, equaling to ¥35.5 RMB, 2011 Purchasing Power Parity [PPP] (53,54); and those living above this poverty line. The YYB intervention was assumed to be rolled out over 12 months based on current YYB practices and the children involved in the program were supposed to take one pack of YYB each day.(55,56) We investigated its costs, effectiveness, and cost-effectiveness, per province and wealth status among children 6-36 month-old. We simulated two coverage scenarios: a low coverage (25%) and a high coverage (75%) scenario.

2.2.2 Data sources

We used data on stunting prevalence and household poverty status from China's Family Panel Studies (CFPS).(38) CFPS is a nationally representative, longitudinal survey launched in 2010 and further conducted in 2012, 2014, and 2016. It covers about 16,000 households across 25 provinces, municipalities, and autonomous regions of China, representing up to 95% of 6-36 month-old Chinese. To calculate stunting prevalence, we standardized height by age and gender using the Z-score method: following the World Health Organization (WHO) guidelines, we defined stunting as height-for-age (HAZ) below - 2 standard deviations (SD, z-scores).(57) CFPS also presents self-reported data on household income per capita: we converted those income values into 2011 PPP in RMB, and converted the international poverty line of $5.50 per day to

¥35.5 RMB per day (2011 PPP).(54) With this poverty line, we identified whether the child in the household would live in poverty or not.

2.2.3 Estimation of health benefits

The health benefits were estimated as the number of stunted children stunting cases that would be averted by YYB, per province and poverty status. First, we estimated the population aged 6-36 months old per province p and poverty status k, denoted POPp,k. Second, we checked whether each child (denoted "i") was stunted by examining whether his/her HAZ (HAZpre,p,k,i, before intervention) was < -2SD. The pre-YYB stunting prevalence in province p and for poverty status k, denoted Spre,p,k, was the probability for the children in that subgroup to be stunted. Third, we used YYB effectiveness from previous literature, denoted Eff, to estimate the impact of YYB on HAZ.(50) We assumed the effectiveness of YYB to be the same for all individuals. The likelihood for a child to be covered by the YYB program is Covp (i.e. the coverage) in each province. Therefore, the expected post-intervention stunting status per child (HAZpost,p,k,i) could be expressed using the following simple static model:

$$HAZ_{post,p,k,i} = HAZ_{pre,p,k,i} + Eff * Cov_p \quad . \quad (1)$$

We then estimated post-intervention stunting prevalence (in province p and for poverty status k i.e. $S_{post,p,k}$) by counting, among all children, how many had $HAZ_{post,p,k,i}$ less than -2SD. Hence, the number of stunting cases averted ($AVERT_{p,k}$) would be calculated as:

$$AVERT_{p,k} = POP_{p,k} * (S_{pre,p,k} - S_{post,p,k}) \quad . \quad (2)$$

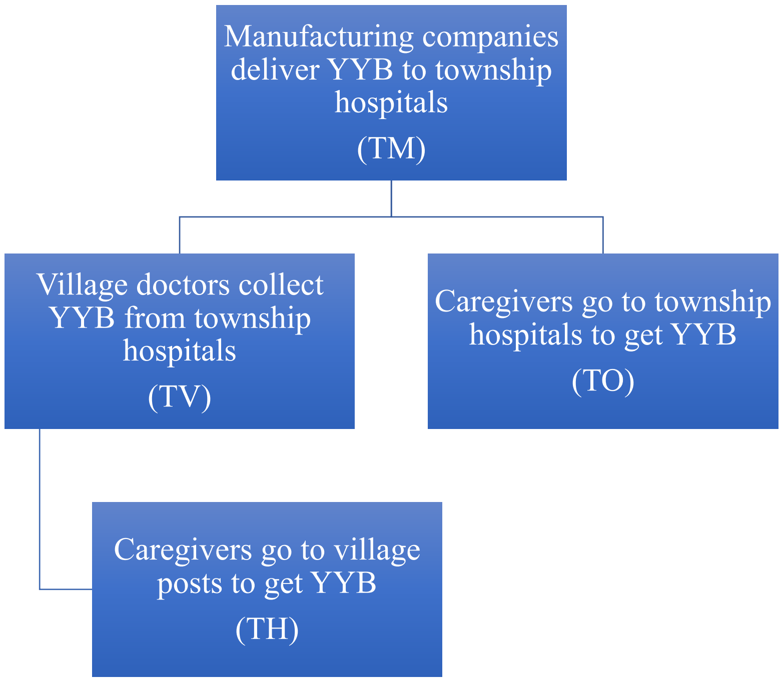
2.2.4 Estimation of costs

We assumed the YYB costs would include fixed costs for procurement and manufacturing, implementation, and advertisement. Additional costs were assumed to vary to cater for transportation availability and accessibility across provinces and the type of YYB delivery to children and households.

Procurement and manufacturing costs (M) were estimated at ¥35.0 cents per YYB pack, including manufacturing, printing for educational materials, personnel training for distribution, and storage.(58–60) Implementation costs (F) include the costs imposed on township hospitals, village health posts, and other related organizations to coordinate and supervise the delivery of YYB; and F was estimated at ¥17.9 cents per pack.(58) Advertisement costs (A) was estimated at ¥16.7 cents per pack and covered raising public awareness and training of staff for implementation.(58)

The transportation costs, denoted $T_{p,k}$ - in province p to deliver to children of wealth status k, included the delivery costs from manufacturing companies to eligible households. $T_{p,k}$ was decomposed into two parts (**Figure 2.1**): first, the transportation costs from manufacturing companies to township hospitals (TM_p), which serve as the distribution location for YYB to households. These costs are usually borne by manufacturing companies and could greatly vary depending on accessibility and distance to township hospitals, from about ¥0.9 to ¥13.5 cent per YYB pack according to empirical data.(58–60) Second, the costs from township hospitals to households, which could be materialized in two ways, depending on delivery type denoted 'delivery type 1' and 'delivery type 2', which are the two major current implemented methods to deliver YYB.(58) Delivery type 1 corresponds to the situation where village doctors come to hospitals every month to collect YYB, and where village health posts serve as the distribution location to obtain YYB for caregivers. The costs borne by the village doctors (TV_p in province p) would be subsidized by the government (58), and the time losses would be borne by caregivers ($TH_{p,k}$, for households of wealth status k in province p) are included. On the other hand, delivery type 2 corresponds to the situation where caregivers would come to township hospitals monthly to get YYB at their own expenses ($TO_{p,k}$, for households of wealth status k in province p).

Figure 2. 1 The types of delivery and associated costs for YYB, from manufacturing companies to eligible children.



Transportation costs (T_p) were expected to vary with province p hence geography, according to two major components: accessibility and distance from manufacturing companies to township hospitals; and delivery type – whether YYB are collected by village doctors from township hospitals or by the caregivers themselves. For the first component, road density is a critical determinant. (58,61) A number of studies on forest management used road density to estimate transportation costs (61–65), which we adapted in this paper. We followed previous practices (64,66), and modelled transportation costs from manufacturing companies to township hospitals per province p based on the local road network density (denoted R_p; see **Appendix Figure 2.1**). We assumed transportation costs would increase linearly with lower road density; and the province with the largest R_p (Shanghai, 208 km/100 km^2 of land area) would face the lower transportation costs (¥0.9 cents per pack), while the province with the lowest R_p (Gansu, 31 km/per 100 km^2) would face the higher transportation costs (¥13.5 cents). Subsequently, we could express the transportation costs from manufacturing companies to township hospitals (in ¥ cents) per pack per province as: $TM_p = 13.5 - (13.5 - 0.9)/(209 - 31)*(R_p - 31)$. For the second component, we modeled two delivery types. Delivery type 1, where village doctors come to township hospitals every month to collect YYB, and the government finances TV = ¥0.9 (58). Caregivers would come to village health posts monthly to obtain YYB. Following previous practices (38,67–69), we calculated caregivers' time costs ($TH_{p,k}$) by multiplying travel time to health posts with provincial-level gross domestic product (GDP) per capita: we estimated caregivers' travel time using CFPS data and provincial-level GDP per capita using China Statistical Yearbook. Delivery type 2, where YYBs are distributed in township hospitals, and caregivers would need to come to township hospitals monthly to obtain YYB. The time costs to township hospitals ($TO_{p,k}$) are borne by caregivers: CFPS did not collect information on travel time to township hospitals, so we imputed the travel time to the nearest town. We multiplied this travel time by province-level GDP per capita to estimate the time costs for caregiver travel to township hospitals ($TO_{p,k}$).

The estimated total transportation costs could then be expressed as: $T_{p,k}= TM_p+ TV_p+ TH_{p,k}$ for delivery type 1; and $T_{p,k}= TM_p+ TO_{p,k}$ for delivery type 2. Subsequently, the total costs per pack could be calculated as: $PP_{p,k} = M + F + A + T_{p,k}$. Lastly, the total costs per province p and wealth status k, for 12 months (365 days), could be estimated as $PP_{p,k}$ multiplied by $POP_{p,k}$, $Cov_{p,k}$, 365 and the number of YYB packs needed for a 12-month intervention.

All the costs were adjusted using 2011 GDP deflator. We reported the data sources for the various components of costs in **Appendix Table 2.1**.

2.2.5 Sensitivity analysis

To test the robustness of our findings, we conducted univariate sensitivity analyses where we varied several key input parameters including the effectiveness of YYB and the cost of the YYB program. First, we examined the impact of YYB effectiveness by halving the original effectiveness Eff. This sensitivity analysis could materialize variations in Eff due to household adherence and acceptability: previous studies showed that adherence of YYB program was around about 80% and acceptability was around 70%.(45,70) Second, we studied the impact of transportation costs, by either halving or doubling transportation costs for delivery types 1 and 2, respectively. This sensitivity analysis could materialize economies of scale: transportation costs per capita may decrease with increasing coverage (e.g. from 25 to 75%); also if many households were living in remote (e.g. mountainous) areas, transportation costs per capita may increase with increasing coverage. In other words, this sensitivity analysis could test the variability in transportation costs across settings. For each sensitivity analysis, we reported on the resulting variations observed by province p and wealth status k.

2.3 Results

We first report on the different components of transportation costs (**Appendix Table 2.2**). The average transportation costs from manufacturing companies to township hospitals were estimated at ¥8.1 cents per pack. On average, caregivers' transportation costs to health posts were ¥0.9 cents per pack; while caregivers' transportation costs to township hospitals were estimated at ¥8.3 cents per pack. **Appendix Table 2.3** presents the estimated transportation costs by YYB delivery type (type 1 vs. type 2). In all provinces, the transportation costs were lower with delivery type 1 (¥9.9-10.2 cents on average) compared with delivery type 2 (¥16.8-25.2 cents on average). This is resulting from the travel time borne by families being greater with delivery type 2 (township hospitals being located further than health posts). We estimated the total costs per pack and the total costs of 25/75% coverage per province and poverty status for a 12-month intervention in **Appendix Tables 2.4** and **2.5**. At 25% coverage, the total costs would be estimated at ¥0.8-1.0 billion for delivery type 1, and ¥0.9-1.2 billion for type 2.

Second, we report on the health gains conferred by YYB. Before the YYB intervention, stunting prevalence would vary substantially by province and poverty status (**Appendix Table 2.6**): Yunnan province would have the highest stunting prevalence at 22-27%; while Beijing, Tianjin, and Shanghai would have the lowest stunting prevalence (about null). With 25% coverage, we estimate that the stunting prevalence in Yunnan would go down to 24/21%, among children living below/above the poverty line; with 75% coverage, it would further decrease to 16/11%. Overall, there would be about 4.0 million stunted children before intervention, including 2.7 million living below the poverty line: Henan with the largest number of stunted children (about 0.4 million); Beijing, Tianjin, Shanghai, and Zhejiang with the lowest number (cumulatively <10,000), see **Appendix Table 2.7**.

The estimated impact of the YYB intervention would then vary greatly by province and wealth status. Nationally, with 25% coverage, about 0.6 million stunting cases could be averted, including 0.4 million cases among children living in poverty. Jiangxi would rank first in terms of stunting cases averted (about 80,000); while Beijing, Tianjin, Shanghai, and Zhejiang would rank last (about 3,000, cumulatively) (see **Table 2.1**).

Lastly, the cost per stunting case averted was generally lower with YYB delivery type 1 than with type 2 (**Table 2.2**). Among all provinces, targeting children in poverty in Chongqing (25% coverage, type 1) would yield the lowest cost per stunting case averted (about ¥800 per stunted case). Conversely, targeting children above the poverty line in Jilin with delivery type 2 would yield the highest cost per stunting case averted (about ¥23,000).

Table 2. 1 Number of stunting cases averted by YYB program by province and poverty status (25% and 75% coverage)

	25% coverage		75% coverage	
Province	**Below poverty line**	**Above poverty line**	**Below poverty line**	**Above poverty line**
Anhui	4,074	5,431	25,799	9,310
Beijing	0	0	0	0
Chongqing	24,076	0	29,694	0
Fujian	4,982	4,095	18,286	25,516
Gansu	9,424	1,261	29,779	5,374
Guangdong	32,623	20,678	76,022	57,978
Guangxi	33,537	5,598	68,566	43,095
Guizhou	14,453	6,509	54,751	22,093
Hebei	48,005	6,549	121,902	20,565
Heilongjiang	8,310	0	34,462	0
Henan	11,561	24,716	117,388	91,953
Hubei	5,958	5,240	30,902	37,334
Hunan	7,273	16,428	71,374	55,224
Jiangsu	5,722	6,383	23,250	32,320
Jiangxi	33,834	45,538	100,104	76,668
Jilin	3,392	746	14,379	13,234
Liaoning	4,588	1,224	14,681	4,468
Shaanxi	11,207	2,074	43,072	13,958
Shandong	33,804	4,243	109,862	27,094
Shanghai	0	0	0	0
Shanxi	8,710	4,296	31,960	23,949
Sichuan	48,825	18,957	146,474	28,088
Tianjin	0	0	0	0
Yunnan	30,226	3,318	106,351	33,686
Zhejiang	2,955	0	6,456	0
Total	**387,538**	**183,284**	**1,275,515**	**621,907**

Notes:
Delivery type 1: manufacturing companies deliver YYB to township hospitals; then village doctors come to township hospitals to collect YYB monthly and caregivers get YYB from village health posts.
Delivery type 2: manufacturing companies deliver YYBs to township hospitals; then caregivers come to township hospitals monthly to obtain YYB.
The (international) poverty line is $5.50 per capita per day using 2011 Purchasing Power Parity.

Table 2. 2 Cost-effectiveness of YYB program by province and poverty status (Cost [¥] per stunting case averted)

Province	25% coverage				75% coverage			
	Delivery type 1		Delivery type 2		Delivery type 1		Delivery type 2	
	Below poverty line	Above poverty line	Below poverty line	Above poverty line	Below poverty line	Above poverty line	Below poverty line	Above poverty line
Anhui	11,680	9,946	18,387	13,192	5,533	17,406	8,710	23,086
Beijing	NA	NA	NA	NA	NA	NA	NA	NA
Chongqing	784	NA	1,215	NA	1,906	NA	2,955	NA
Fujian	4,179	5,972	4,469	6,336	3,416	2,876	3,653	3,051
Gansu	3,416	10,989	3,656	10,873	3,244	7,733	3,471	7,651
Guangdong	1,859	2,332	2,473	2,484	2,393	2,495	3,183	2,658
Guangxi	2,013	7,556	2,361	7,939	2,954	2,944	3,465	3,094
Guizhou	3,662	3,594	4,248	3,567	2,900	3,177	3,364	3,153
Hebei	1,734	7,291	2,074	7,756	2,048	6,966	2,450	7,410
Heilongjiang	2,751	NA	2,885	NA	1,990	NA	2,087	NA
Henan	9,556	3,801	10,075	3,992	2,824	3,065	2,977	3,219
Hubei	4,854	8,760	5,420	10,266	2,808	3,688	3,135	4,322
Hunan	7,855	3,648	9,760	4,273	2,401	3,255	2,984	3,813
Jiangsu	2,939	8,767	3,093	9,241	2,169	5,194	2,284	5,475
Jiangxi	1,577	968	1,701	1,058	1,599	1,724	1,725	1,886
Jilin	4,186	18,866	4,517	23,383	2,963	3,189	3,197	3,952
Liaoning	3,678	11,810	5,528	11,810	3,448	9,708	5,182	9,708
Shaanxi	2,953	6,891	3,654	7,837	2,305	3,072	2,852	3,494
Shandong	2,000	13,134	2,151	13,083	1,846	6,170	1,985	6,146
Shanghai	NA	NA	NA	NA	NA	NA	NA	NA
Shanxi	2,861	4,501	3,046	4,523	2,339	2,422	2,490	2,434
Sichuan	2,154	1,443	2,245	1,705	2,154	2,923	2,245	3,453
Tianjin	NA	NA	NA	NA	NA	NA	NA	NA
Yunnan	2,309	6,689	3,487	7,308	1,969	1,976	2,973	2,159
Zhejiang	2,697	NA	2,710	NA	3,703	NA	3,721	NA

Notes:
Delivery type 1: manufacturing companies deliver YYB to township hospitals; then village doctors come to township hospitals to collect YYB monthly and caregivers get YYB from village health posts.
Delivery type 2: manufacturing companies deliver YYBs to township hospitals; then caregivers come to township hospitals monthly to obtain YYB.
The (international) poverty line is $5.50 per capita per day using 2011 Purchasing Power Parity.

2.4 Sensitivity analysis

First, when halving the effect size of YYB, as expected, the cost per stunting case averted increased compared with the base-case scenario. Expectedly, the costs per stunting case averted were maintained lower with delivery type 1 vs type 2; and the cost per stunting case averted would remain the lowest in Chongqing (about ¥1,600 with delivery type 1 targeting children in poverty), while the cost per stunting case averted would remain the highest in Anhui (about ¥51,200) (**Table 2.3**).

Second, when the cost of YYB was halved, our key distributional findings would be maintained (**Table 2.4**). Notably, targeting children below the poverty line in Chongqing with delivery type 1 would still have the lowest cost per stunting case averted (about ¥700). When the cost of YYB was doubled, our key distributional findings would hold as well (**Table 2.4**).

Table 2. 3 Cost-effectiveness of YYB program by province and poverty status if the effect size of YYB was halved (Cost [¥] per stunting case averted)

Province	25% coverage				75% coverage			
	Delivery type 1		Delivery type 2		Delivery type 1		Delivery type 2	
	Below poverty line	Above poverty line	Below poverty line	Above poverty line	Below poverty line	Above poverty line	Below poverty line	Above poverty line
Anhui	18,418	38,568	28,995	51,155	11,051	24,302	17,396	32,233
Beijing	NA	NA	NA	NA	NA	NA	NA	NA
Chongqing	1,593	NA	2,468	NA	3,987	NA	6,179	NA
Fujian	6,662	16,116	7,125	17,096	6,334	6,059	6,774	6,428
Gansu	5,822	44,251	6,230	43,785	6,907	15,081	7,391	14,922
Guangdong	4,371	5,087	5,815	5,419	4,538	4,784	6,038	5,096
Guangxi	3,788	11,137	4,442	11,702	6,181	6,093	7,249	6,402
Guizhou	5,851	9,590	6,786	9,517	5,662	6,959	6,567	6,906
Hebei	4,043	11,381	4,838	12,107	4,110	12,053	4,918	12,822
Heilongjiang	5,157	NA	5,408	NA	3,961	NA	4,154	NA
Henan	19,422	9,672	20,475	10,157	5,407	6,102	5,701	6,408
Hubei	11,116	15,865	12,412	18,591	5,638	7,405	6,295	8,678
Hunan	12,386	8,698	15,389	10,189	5,031	6,353	6,250	7,442
Jiangsu	4,776	10,065	5,028	10,609	4,607	10,145	4,849	10,693
Jiangxi	2,878	1,995	3,104	2,181	3,204	3,447	3,455	3,769
Jilin	9,070	37,732	9,787	46,766	6,099	5,917	6,581	7,333
Liaoning	14,448	26,967	21,717	26,967	8,501	18,791	12,778	18,791
Shaanxi	6,167	14,303	7,631	16,268	4,468	6,256	5,529	7,116
Shandong	3,947	33,320	4,246	33,191	3,712	14,167	3,992	14,112
Shanghai	NA	NA	NA	NA	NA	NA	NA	NA
Shanxi	5,163	12,912	5,497	12,976	4,609	4,699	4,906	4,722
Sichuan	4,469	3,074	4,658	3,632	4,545	6,024	4,737	7,117
Tianjin	NA	NA	NA	NA	NA	NA	NA	NA
Yunnan	4,221	9,083	6,373	9,923	3,844	4,140	5,803	4,524
Zhejiang	5,556	NA	5,583	NA	8,091	NA	8,132	NA

Notes:

Delivery type 1: manufacturing companies deliver YYB to township hospitals; then village doctors come to township hospitals to collect YYB monthly and caregivers get YYB from village health posts.

Delivery type 2: manufacturing companies deliver YYB to township hospitals; then caregivers come to township hospitals monthly to obtain YYB.

The (international) poverty line is $5.50 per capita per day using 2011 Purchasing Power Parity.

Table 2. 4 Cost-effectiveness of YYB program by province and poverty status if the transportation costs (both for delivery type 1 and delivery type 2) are halved or doubled (Cost [¥] per stunting case averted)

Province	25% coverage				75% coverage			
	Delivery type 1		Delivery type 2		Delivery type 1		Delivery type 2	
	Below poverty line	Above poverty line	Below poverty line	Above poverty line	Below poverty line	Above poverty line	Below poverty line	Above poverty line
	The cost per stunting case averted assuming the transportation costs of YYB were halved							
Anhui	11,133	9,510	14,486	11,133	5,273	16,642	6,862	19,482
Beijing	NA	NA	NA	NA	NA	NA	NA	NA
Chongqing	745	NA	960	NA	1,811	NA	2,336	NA
Fujian	3,894	5,568	4,039	5,749	3,182	2,681	3,301	2,768
Gansu	3,120	9,967	3,240	9,909	2,962	7,014	3,076	6,973
Guangdong	1,754	2,205	2,061	2,281	2,258	2,359	2,654	2,440
Guangxi	1,830	6,875	2,004	7,067	2,685	2,679	2,940	2,754
Guizhou	3,422	3,384	3,715	3,371	2,710	2,991	2,942	2,979
Hebei	1,622	6,821	1,792	7,054	1,916	6,517	2,117	6,739
Heilongjiang	2,513	NA	2,581	NA	1,818	NA	1,867	NA
Henan	9,177	3,646	9,436	3,741	2,711	2,940	2,788	3,017
Hubei	4,544	8,349	4,827	9,102	2,628	3,516	2,792	3,833
Hunan	7,379	3,389	8,332	3,702	2,256	3,024	2,547	3,303
Jiangsu	2,815	8,403	2,892	8,640	2,078	4,979	2,135	5,119
Jiangxi	1,471	903	1,533	948	1,492	1,610	1,555	1,690
Jilin	3,838	17,372	4,003	19,630	2,716	2,936	2,834	3,318
Liaoning	3,417	11,005	4,342	11,005	3,203	9,046	4,071	9,046
Shaanxi	2,747	6,413	3,097	6,886	2,144	2,859	2,417	3,070
Shandong	1,907	12,464	1,983	12,439	1,760	5,856	1,830	5,844
Shanghai	NA	NA	NA	NA	NA	NA	NA	NA
Shanxi	2,668	4,196	2,760	4,207	2,181	2,258	2,257	2,264
Sichuan	1,984	1,334	2,030	1,465	1,984	2,700	2,030	2,965
Tianjin	NA	NA	NA	NA	NA	NA	NA	NA
Yunnan	2,135	6,180	2,723	6,489	1,820	1,826	2,322	1,917
Zhejiang	2,525	NA	2,531	NA	3,466	NA	3,475	NA

Table 2. 4 (Continued) Cost-effectiveness of YYB program by province and poverty status if the transportation costs (both for delivery type 1 and delivery type 2) are halved or doubled (Cost [¥] per stunting case averted)

Province	25% coverage				75% coverage			
	Delivery type 1		Delivery type 2		Delivery type 1		Delivery type 2	
	Below poverty line	Above poverty line	Below poverty line	Above poverty line	Below poverty line	Above poverty line	Below poverty line	Above poverty line
	The cost per stunting case averted assuming the transportation costs of YYB were doubled							
Anhui	12,775	10,820	26,189	17,311	6,051	18,934	12,405	30,295
Beijing	NA	NA	NA	NA	NA	NA	NA	NA
Chongqing	862	NA	1,724	NA	2,096	NA	4,193	NA
Fujian	4,749	6,781	5,330	7,508	3,882	3,265	4,356	3,615
Gansu	4,009	13,032	4,488	12,801	3,806	9,171	4,261	9,008
Guangdong	2,067	2,585	3,295	2,890	2,661	2,766	4,242	3,092
Guangxi	2,380	8,918	3,076	9,683	3,492	3,475	4,513	3,773
Guizhou	4,143	4,014	5,313	3,959	3,281	3,548	4,208	3,499
Hebei	1,957	8,231	2,638	9,162	2,312	7,864	3,117	8,753
Heilongjiang	3,225	NA	3,493	NA	2,333	NA	2,527	NA
Henan	10,315	4,112	11,351	4,493	3,048	3,316	3,354	3,623
Hubei	5,475	9,581	6,606	12,593	3,167	4,034	3,821	5,302
Hunan	8,808	4,165	12,616	5,415	2,692	3,717	3,857	4,833
Jiangsu	3,186	9,495	3,495	10,442	2,352	5,626	2,581	6,187
Jiangxi	1,789	1,097	2,036	1,277	1,814	1,954	2,065	2,276
Jilin	4,883	21,854	5,545	30,888	3,456	3,694	3,925	5,221
Liaoning	4,199	13,422	7,900	13,422	3,937	11,033	7,406	11,033
Shaanxi	3,365	7,846	4,767	9,739	2,627	3,498	3,721	4,342
Shandong	2,185	14,472	2,487	14,371	2,017	6,799	2,296	6,751
Shanghai	NA	NA	NA	NA	NA	NA	NA	NA
Shanxi	3,249	5,110	3,618	5,155	2,656	2,750	2,958	2,774
Sichuan	2,492	1,663	2,675	2,187	2,492	3,368	2,675	4,428
Tianjin	NA	NA	NA	NA	NA	NA	NA	NA
Yunnan	2,659	7,707	5,013	8,946	2,267	2,277	4,274	2,643
Zhejiang	3,042	NA	3,069	NA	4,176	NA	4,213	NA

Notes:

Delivery type 1: manufacturing companies deliver YYB to township hospitals; then village doctors come to township hospitals to collect YYB monthly and caregivers get YYB from village health posts.

Delivery type 2: manufacturing companies deliver YYB to township hospitals; then caregivers come to township hospitals monthly to obtain YYB.

The (international) poverty line is $5.50 per capita per day using 2011 Purchasing Power Parity

2.5 Discussion

We assessed the distributional consequences of the potential rollout of a YYB program on stunting prevalence in China. We found that the estimated costs to avert a stunting case would vary substantially by province, poverty status, delivery method, and coverage of YYB program, from as low as ¥800 (Chongqing province) to as high as ¥23,000 (Jilin province). Chongqing, Jiangxi, Sichuan, Guangdong, and Guangxi would generally present a lower cost to avert a stunting case; while Anhui, Gansu, and Jilin would present higher costs. With limited financial resources and the Chinese government aiming at maximizing health gains in the population, the provinces showing a lower cost to avert a stunting case would likely be prioritized.

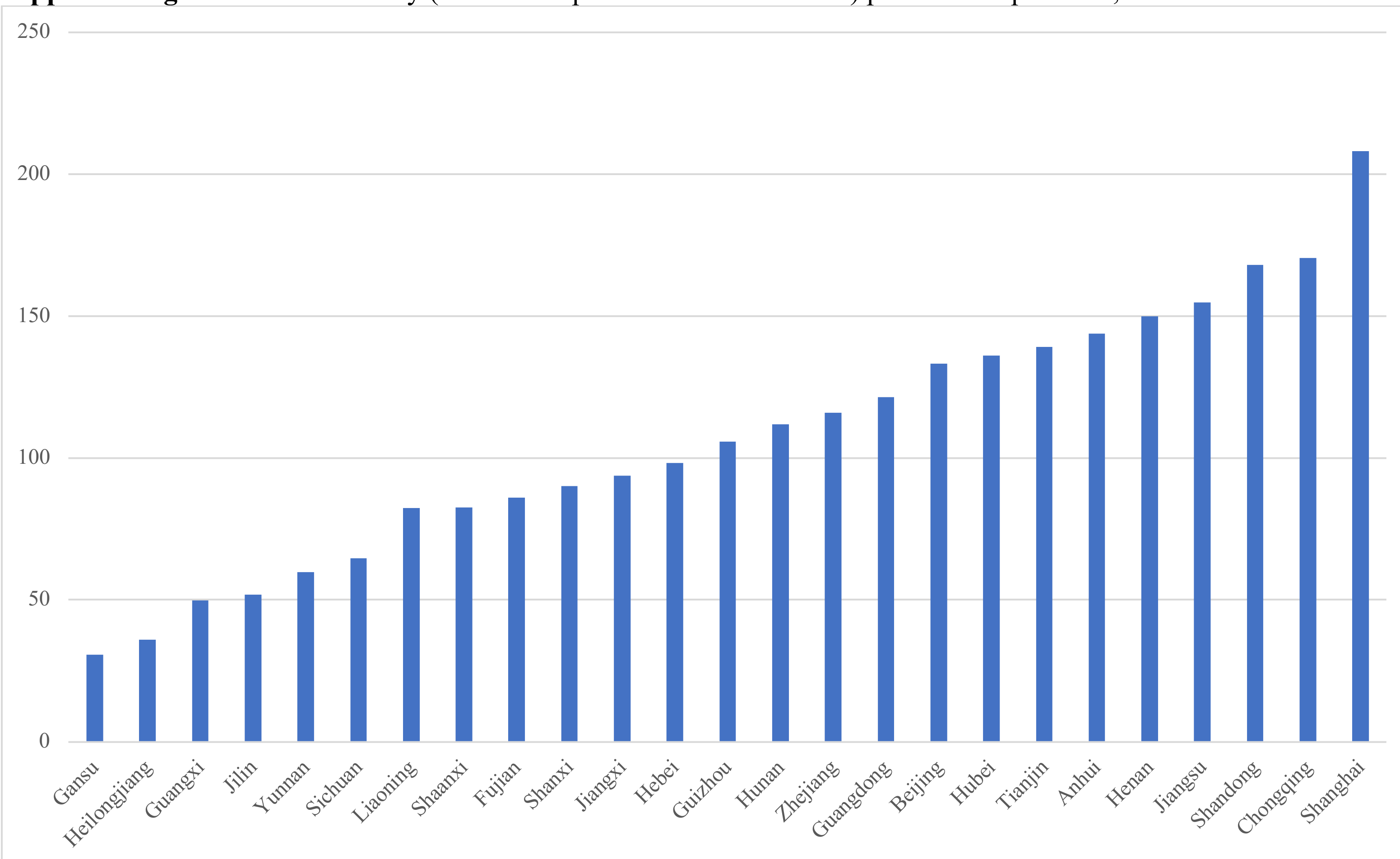
Moreover, in most provinces, the costs to avert a stunting case would be cheaper among children living in poverty, pointing to both the efficient and pro-poor potential of YYB rollout in China. It would also be cheaper to avert stunting at higher YYB coverage (75 vs. 25%) with notable exceptions (Chongqing, Guangdong, Guangxi, Hebei, Jiangxi, and Zhejiang provinces).

Delivery-wise, we find that the cost per stunting case averted would be lower in almost all provinces if YYBs were collected by village doctors from township hospitals and then caregivers would obtain them from village doctors, compared to caregivers coming to township hospitals to collect YYBs directly. The former delivery type 1 is the dominant delivery method in China;(58) yet, the latter delivery type 2 would lower the government cost burden.(71) Our study accounted for the costs borne by caregivers and found it more costly when caregivers travel to township hospitals to obtain YYB (delivery type 2).

Our analysis presents a number of limitations. First, there is uncertainty in several of our input parameters, including, for example transportation costs from manufacturing companies to township hospitals (TM). Estimation of TM was based on the assumptions that TM would increase linearly with lower road density: although similar modeling was applied previously (61–65), TM may not vary linearly with road density, but discontinuously as transport means used may change with road density (e.g. trucks could play a dominant role in places with higher road density).(72) Although our sensitivity analysis allowed for variation in transportation costs, due to limited data, we still assumed similar TM costs for reaching all households within a province. Second, YYB coverage was assumed to be either 25 or 75%, and we did not seek for an optimal coverage target (i.e. most cost-effective) for each province; neither did we question the feasibility of our assumed coverage rates. Third, we relied on self-reported data on children's height from CFPS: CFPS was the only survey with nationally representative data on child stunting status that could allow us to analyze the distributional impact of YYB, yet self-reported data may suffer from several issues including recall bias. Fourth, ECEA is only one method for priority setting, and decision-making is a complicated process. In addition to cost-effectiveness analysis or ECEA, decision-making processes should incorporate multiple considerations such as ethical, social and political factors. However, by using ECEA, we intended here to focus on the equity impact of YYB, which is essential in such a large heterogeneous country like China. Fifth, our study only considered rural China and thus ignored the country's large urban-rural disparities. Moreover, we adopted the World Bank's international poverty line of $5.50 per day (equaling to ¥35.5 RMB, 2011 Purchasing Power Parity), which could be revisited. For example, the gross domestic product per capita in Jiangsu was around ¥95,000 in 2016, more than three times higher than in Gansu the same year (about ¥28,000); hence using the same poverty line across provinces may present some limitations. Sixth, though we considered adherence rates in our sensitivity analyses, we were uncertain how adherence would specifically affect effectiveness. For example, if children only took YYB for 9 months (instead of 12), the adherence rate would be 75%, but the effectiveness might be maintained as the effectiveness of a 12-month intervention. Lastly, the effects of YYB can be multifaceted, including reducing anemia prevalence, strengthening anthropometric growth, improving cognitive development, which would add to the overall benefits of YYB beyond solely averting stunting. Therefore, we did not include estimation of disability-adjusted life years (DALYs) averted in our study as stunting-related DALYs could only account for a small proportion of the total impact of YYB. Despite the limitations, our study is the first one that clearly stresses the distributional and equity implications of potential YYB rollout in China, and points to the specific locations and provinces where YYB should be prioritized in terms of both efficient and equitable allocation. Our work highlights the pro-poor nature of YYB and how its rollout could redistribute population health in large and unequal low- and middle-income countries like China. Future work should expand on our analysis by incorporating essential features capturing the feasibility and acceptability of different delivery scenarios.

Appendix for Chapter 2

Appendix Figure 2.1 Road density (km of road per 100km^2 of land area) per Chinese province, 2015.



Appendix Table 2.1 Cost type, symbol, definition, and source

Cost type	**Symbol**	**Definition**	**Source**
1. Transportation costs	$T_{p,k}$	The costs to deliver YYB from manufacturing companies to eligible households	Authors' assumption
a. Transportation costs from manufacturing companies to township hospitals	TM_p	The costs to deliver YYB from manufacturing companies to township hospitals	Based on road density
b. Transportation costs from township hospitals to village health posts	TV_p	The costs to deliver YYB from township hospitals to village health posts	China Development Research Foundation (58)
c. Transportation costs from village health posts to eligible households	$TH_{p,k}$	The costs to deliver YYB from village health posts to eligible households (borne by caregivers)	Based on caregivers' travel time and wages
d. Transportation costs from township hospitals directly to eligible households	$TO_{p,k}$	The costs to deliver YYB from township hospitals to eligible households (borne by caregivers)	Based on caregivers' travel time and wages
2. Procurement and manufacturing costs	$M_{p,k}$	Includes: manufacturing, printing for educational materials, personnel training for distribution, and storage	China Development Research Foundation (58)
3. Implementation costs	$F_{p,k}$	Includes: the costs imposed on township hospitals, village health posts, and other related organizations to coordinate and supervise the delivery of YYB	China Development Research Foundation (58)
4. Advertisement costs	$A_{p,k}$	Includes: raising public awareness and training of staff for implementation	China Development Research Foundation (58)

Appendix Table 2.2 Estimated transportation costs per pack per province and poverty status (¥ cents)

Province	From manufacturing company to township hospitals (TM_p)	Caregiver transportation costs to health posts ($TH_{k,p}$)		Caregiver transportation costs to township hospitals ($TO_{k,p}$)	
		Below poverty line	Above poverty line	Below poverty line	Above poverty line
Anhui	5.5	0.8	0.3	45.8	26.1
Beijing	6.2	NA	NA	NA	NA
Chongqing	3.6	3.2	1.0	46.6	4.8
Fujian	9.6	0.5	0.4	7.0	6.2
Gansu	13.5	0.2	1.5	7.0	1.5
Guangdong	7.1	0.8	0.5	27.6	6.5
Guangxi	12.1	2.5	2.3	18.1	7.5
Guizhou	8.2	1.4	0.1	15.1	0.4
Hebei	8.7	0.7	0.7	17.3	6.7
Heilongjiang	13.1	0.5	2.2	5.5	2.9
Henan	5.0	0.1	0.3	5.1	5.0
Hubei	6.0	3.3	0.3	13.5	14.4
Hunan	7.7	1.0	2.9	21.1	17.7
Jiangsu	4.7	0.8	0.7	5.7	5.7
Jiangxi	9.0	0.9	0.8	8.1	9.2
Jilin	12.0	1.0	0.2	8.5	20.9
Liaoning	9.8	0.8	0.3	42.5	1.2
Shaanxi	9.8	0.6	0.5	20.7	12.5
Shandong	3.7	2.5	3.3	9.2	3.9
Shanghai	0.9	0.1	0.1	5.4	2.5
Shanxi	9.3	0.7	0.7	6.8	2.0
Sichuan	11.1	1.0	0.5	5.4	16.3
Tianjin	5.8	0.8	0.8	22.1	21.8
Yunnan	11.4	0.1	0.2	42.8	8.7
Zhejiang	7.5	1.8	0.7	3.1	2.7

Notes: the (international) poverty line is set at $5.50 per capita per day using 2011 Purchasing Power Parity. Subsidies to village doctors to collect YYB from township hospitals to village health posts are assumed constant across provinces: TV = ¥0.90.

Appendix Table 2.3 Estimated total transportation costs per pack by delivery type per province and poverty status (¥ cents)

Province	**Delivery type 1 ($T_{p,k}$= TM_p+ TV_p+ $TH_{p,k}$)**		**Delivery type 2 ($T_{p,k}$= TM_p+ $TO_{p,k}$)**	
	Below poverty line	**Above poverty line**	**Below poverty line**	**Above poverty line**
Anhui	7	7	51	32
Beijing	NA	NA	NA	NA
Chongqing	8	6	50	8
Fujian	11	11	17	16
Gansu	15	16	21	15
Guangdong	9	9	35	14
Guangxi	16	15	30	20
Guizhou	11	9	23	9
Hebei	10	10	26	15
Heilongjiang	15	16	19	16
Henan	6	6	10	10
Hubei	10	7	20	20
Hunan	10	12	29	25
Jiangsu	6	6	10	10
Jiangxi	11	11	17	18
Jilin	14	13	21	33
Liaoning	12	11	52	11
Shaanxi	11	11	31	22
Shandong	7	8	13	8
Shanghai	2	2	6	3
Shanxi	11	11	16	11
Sichuan	13	13	17	27
Tianjin	8	8	28	28
Yunnan	12	13	54	20
Zhejiang	10	9	11	10

Notes:
Delivery type 1: manufacturing companies deliver YYB to township hospitals; then village doctors come to township hospitals to collect YYB monthly and caregivers get YYB from village health posts.
Delivery type 2: manufacturing companies deliver YYB to township hospitals; then caregivers come to township hospitals monthly to obtain YYB.
The (international) poverty line is $5.50 per capita per day using 2011 Purchasing Power Parity.

Appendix Table 2.4 Estimated total costs per pack by delivery type per province and poverty status (¥ cents)

Province	Delivery type 1		Delivery type 2	
	Below poverty line	**Above poverty line**	**Below poverty line**	**Above poverty line**
Anhui	77	76	121	101
Beijing	NA	NA	NA	NA
Chongqing	77	75	120	78
Fujian	81	81	86	85
Gansu	84	86	90	85
Guangdong	78	78	104	83
Guangxi	85	85	100	89
Guizhou	80	79	93	78
Hebei	80	80	96	85
Heilongjiang	84	86	88	86
Henan	76	76	80	80
Hubei	80	77	89	90
Hunan	79	81	98	95
Jiangsu	76	76	80	80
Jiangxi	80	80	87	88
Jilin	84	83	90	103
Liaoning	81	81	122	81
Shaanxi	81	81	100	92
Shandong	77	78	83	77
Shanghai	72	72	76	73
Shanxi	81	81	86	81
Sichuan	83	82	86	97
Tianjin	77	77	98	97
Yunnan	82	82	124	90
Zhejiang	80	79	80	80

Notes:

Delivery type 1: manufacturing companies deliver YYB to township hospitals; then village doctors come to township hospitals to collect YYB monthly and caregivers get YYB from village health posts.

Delivery type 2: manufacturing companies deliver YYB to township hospitals; then caregivers come to township hospitals monthly to obtain YYB.

The (international) poverty line is $5.50 per capita per day using 2011 Purchasing Power Parity.

Appendix Table 2.5 Estimated total costs for a 12-month YYB rollout by province and poverty status (25% and 75% coverage, ¥ million)

	25% coverage				**75% coverage**			
	Delivery type 1		**Delivery type 2**		**Delivery type 1**		**Delivery type 2**	
Province	**Below poverty line**	**Above poverty line**	**Below poverty line**	**Above poverty line**	**Below poverty line**	**Above poverty line**	**Below poverty line**	**Above poverty line**
Anhui	47.6	54.0	74.9	71.6	142.7	162.0	224.7	214.9
Beijing	NA	NA	NA	NA	NA	NA	NA	NA
Chongqing	18.9	18.3	29.2	19.0	56.6	55.0	87.7	57.1
Fujian	20.8	24.5	22.3	25.9	62.5	73.4	66.8	77.8
Gansu	32.2	13.9	34.5	13.7	96.6	41.6	103.4	41.1
Guangdong	60.6	48.2	80.7	51.4	181.9	144.6	242.0	154.1
Guangxi	67.5	42.3	79.2	44.4	202.6	126.9	237.6	133.3
Guizhou	52.9	23.4	61.4	23.2	158.8	70.2	184.2	69.7
Hebei	83.2	47.8	99.6	50.8	249.7	143.3	298.7	152.4
Heilongjiang	22.9	13.3	24.0	13.3	68.6	40.0	71.9	39.9
Henan	110.5	93.9	116.5	98.7	331.4	281.8	349.4	296.0
Hubei	28.9	45.9	32.3	53.8	86.8	137.7	96.9	161.4
Hunan	57.1	59.9	71.0	70.2	171.4	179.8	212.9	210.6
Jiangsu	16.8	56.0	17.7	59.0	50.4	167.9	53.1	176.9
Jiangxi	53.4	44.1	57.5	48.2	160.1	132.2	172.6	144.6
Jilin	14.2	14.1	15.3	17.4	42.6	42.2	46.0	52.3
Liaoning	16.9	14.5	25.4	14.5	50.6	43.4	76.1	43.4
Shaanxi	33.1	14.3	40.9	16.3	99.3	42.9	122.8	48.8
Shandong	67.6	55.7	72.7	55.5	202.8	167.2	218.1	166.5
Shanghai	0.1	3.3	0.1	3.4	0.4	9.9	0.4	10.1
Shanxi	24.9	19.3	26.5	19.4	74.8	58.0	79.6	58.3
Sichuan	105.1	27.4	109.6	32.3	315.4	82.1	328.8	97.0
Tianjin	1.5	4.6	1.9	5.8	4.6	13.8	5.8	17.4
Yunnan	69.8	22.2	105.4	24.2	209.4	66.6	316.2	72.7
Zhejiang	8.0	33.4	8.0	33.9	23.9	100.2	24.0	101.6
Total	**1,014.6**	**794.2**	**1,206.6**	**866.0**	**3,043.8**	**2,382.5**	**3,619.7**	**2,597.9**

Notes:

Delivery type 1: manufacturing companies deliver YYB to township hospitals; then village doctors come to township hospitals to collect YYB monthly and caregivers get YYB from village health posts.

Delivery type 2: manufacturing companies deliver YYBs to township hospitals; then caregivers come to township hospitals monthly to obtain YYB.

The (international) poverty line is $5.50 per capita per day using 2011 Purchasing Power Parity.

Appendix Table 2.6 Stunting prevalence by province and poverty status

Province	Before intervention		25% intervention coverage		75% intervention coverage	
	Below poverty line	**Above poverty line**	**Below poverty line**	**Above poverty line**	**Below poverty line**	**Above poverty line**
Anhui	7.1%	2.3%	6.5%	1.6%	3.3%	1.1%
Beijing	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Chongqing	11.1%	0.0%	2.1%	0.0%	0.0%	0.0%
Fujian	15.4%	13.3%	13.6%	12.1%	8.9%	5.7%
Gansu	21.4%	16.2%	19.1%	15.5%	14.2%	13.2%
Guangdong	23.1%	17.6%	19.2%	14.5%	14.1%	9.0%
Guangxi	17.7%	13.8%	13.8%	12.8%	9.8%	5.9%
Guizhou	25.7%	15.8%	23.7%	13.8%	18.2%	9.0%
Hebei	17.9%	6.3%	13.7%	5.3%	7.2%	3.1%
Heilongjiang	22.9%	0.0%	20.1%	0.0%	11.3%	0.0%
Henan	14.5%	13.0%	13.8%	11.2%	7.2%	6.2%
Hubei	25.0%	18.0%	23.5%	17.2%	17.2%	12.3%
Hunan	18.2%	15.2%	17.3%	13.1%	9.2%	8.3%
Jiangsu	16.7%	5.0%	14.3%	4.2%	7.1%	1.0%
Jiangxi	25.6%	22.9%	20.9%	15.3%	11.8%	10.1%
Jilin	20.0%	14.3%	18.2%	13.9%	12.3%	7.2%
Liaoning	19.5%	2.3%	17.5%	1.7%	13.1%	0.0%
Shaanxi	25.0%	16.2%	22.5%	15.1%	15.4%	9.0%
Shandong	18.8%	11.5%	15.3%	11.0%	7.4%	8.1%
Shanghai	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Shanxi	23.1%	15.8%	20.5%	14.2%	13.7%	6.7%
Sichuan	22.5%	7.7%	19.0%	2.5%	12.0%	0.0%
Tianjin	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Yunnan	27.4%	22.0%	24.2%	20.9%	16.0%	10.6%
Zhejiang	5.9%	0.0%	3.2%	0.0%	0.0%	0.0%

Note: The (international) poverty line is $5.50 per capita per day using 2011 Purchasing Power Parity.

Appendix Table 2.7 Estimated number of stunting cases by province and poverty status.

Province	Before intervention		25% intervention coverage		75% intervention coverage	
	Below poverty line	Above poverty line	Below poverty line	Above poverty line	Below poverty line	Above poverty line
Anhui	48,203	17,843	44,130	12,413	22,404	8,534
Beijing	0	0	0	0	0	0
Chongqing	29,694	0	5,618	0	0	0
Fujian	43,536	44,384	38,554	40,289	25,250	18,868
Gansu	89,467	28,834	80,043	27,573	59,688	23,460
Guangdong	195,607	118,865	162,984	98,187	119,585	60,887
Guangxi	153,474	75,288	119,937	69,690	84,908	32,193
Guizhou	186,196	51,376	171,743	44,867	131,445	29,284
Hebei	204,197	40,934	156,192	34,385	82,295	20,369
Heilongjiang	68,209	0	59,899	0	33,747	0
Henan	232,063	176,300	220,502	151,584	114,675	84,347
Hubei	99,301	117,898	93,343	112,658	68,398	80,564
Hunan	143,720	122,676	136,447	106,248	72,346	67,451
Jiangsu	40,487	40,399	34,766	34,016	17,237	8,080
Jiangxi	186,086	137,474	152,252	91,936	85,982	60,807
Jilin	37,278	26,654	33,886	25,908	22,899	13,420
Liaoning	44,489	4,468	39,901	3,244	29,808	0
Shaanxi	112,066	31,405	100,860	29,331	68,994	17,447
Shandong	181,091	90,921	147,287	86,678	71,229	63,827
Shanghai	0	0	0	0	0	0
Shanxi	78,306	41,566	69,596	37,270	46,346	17,617
Sichuan	313,873	28,088	265,049	9,131	167,399	0
Tianjin	0	0	0	0	0	0
Yunnan	255,616	65,168	225,390	61,851	149,265	31,482
Zhejiang	6,456	0	3,502	0	0	0
Total	**2,749,415**	**1,260,542**	**2,361,878**	**1,077,258**	**1,473,900**	**638,635**

Note: The (international) poverty line is $5.50 per capita per day using 2011 Purchasing Power Parity.

Chapter 3

Prenatal exposure to sand and dust storms and children's cognitive function in China: a quasi-experimental study

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Published on May 2018 in *The Lancet Planetary Health*

Full citation: Li Z, Chen L, Li M, Cohen J. Prenatal exposure to sand and dust storms and children's cognitive function in China: a quasi-experimental study. *The Lancet Planetary Health.* 2018 May 31;2(5):e214-22.

Abstract

Background

While there is evidence that sand-and-dust storms (SDS) can have adverse health effects, the impact of these storms on children's cognitive function is unexplored. This study examines whether prenatal exposure to SDS influences children's cognitive function and, if so, whether harmful effects of SDS vary by the trimester of exposure.

Methods

Using nationally representative data between 2010 and 2014 from China, we adopted four indicators of children's cognitive function: mathematics test scores, word-recognition test scores, the age the child began speaking whole sentences, and the age the child began counting from one to ten. Since the annual incidence of SDS is highly variable and is largely unpredictable, we use a region- and year- fixed effects model to compare the cognitive function of children born in the same region and year but with varying incidence of prenatal SDS exposure. We also explore whether the impact of SDS varies by the specific month of prenatal exposure.

Results

We included 1,236 observations for the analysis on mathematics and word-recognition tests, 2,693 (1,951) observations for the age the child began speaking whole sentences (counting from one to ten). We find that prenatal exposure to SDS is negatively associated with children's cognitive function. Every ten additional days of prenatal SDS exposure is significantly associated with a 0.20 (95%CI: 0.06-0.35) standard deviation (SD) reduction in word test scores, 0.04 (95%CI: 0.00-0.09) additional months to begin speaking sentences, and 0.14 (95%CI: 0.03-0.25) additional months to begin counting. We further find that the negative effects of SDS exposure are most marked in the 6^{th} and 7^{th} gestational months. Ten additional days of prenatal

exposure to SDS in the 7^{th} gestational month is associated with a 0.18 (95%CI: 0.10-0.25) SD reduction in math test scores, a 0.34 (95%CI: 0.18-0.50) SD reduction in word test scores, an additional 0.33 (95%CI: 0.07, 0.59) months to begin speaking sentences, and an additional 0.20 (95%CI: 0.04, 0.35) months to begin counting.

Discussion

These results suggest that protections for pregnant women in the critical periods of fetal brain development could generate long-lasting benefits for the cognitive function of the next generation.

3.1 Introduction

Sand and dust storms (SDSs) are a worldwide phenomenon that happens with high incidence in countries located in the Middle East, Central and South Asia, Central and North Africa, and Australia, affecting roughly two billion people living in these regions.(73) SDSs occur when a combination of strong winds and loose dry soil raise large quantities of dust into the air in arid and semi-arid areas.(74) The storms are capable of transporting sediment over thousands of kilometers. For example, Saharan dust is transported to Amazonia, North America, Europe, the Middle East and China.

SDSs in China are concentrated in the north of the country, with 14 of the 34 provinces and 65% of the total land area at risk. SDSs in China are highly seasonal, occurring mostly in the spring months. (75) The incidence and intensity of the storms fluctuates greatly from year to year, depending on certain metrological conditions and the dryness of the land.(76) Sand and dust storms contain complex compositions, with atmospheric mineral dust as the major component (85% to 94%), along with carbonates, spores, fungi, and bacteria.(74)

There is mounting evidence that SDSs are associated with adverse effects on child health, including increases in mortality and the risk of respiratory, cardiovascular, and cardiopulmonary diseases.(76–78) Several studies show evidence that prenatal exposure to dust events significantly lowers birth weight, reduces gestational time, and increases infant mortality.(79,80) Although previous studies have demonstrated short-term effects of SDSs on infants' physical health, the longer-term effects of SDSs on children's cognitive function remained unexplored. Animal studies show that inhaled air pollutants can be translocated from the respiratory system directly to the central nervous system, affecting cognitive processes.(81–83) Human studies have found negative associations between prenatal exposure to some types of air pollutants, such as polycyclic aromatic hydrocarbon, NO2, fine and coarse particles, and children's cognitive function.(84–87) Moreover, since each fetal body part has its own critical period of development, several epidemiological and economic studies have analyzed the relationship between air pollutants and health outcomes by the trimester of exposure, with inconclusive results regarding which trimester of exposure has the most critical impact on health outcomes.

An important limitation of most previous studies is that the observed relationships could be biased by unobserved confounders that are correlated with both exposure to air pollutants and child outcomes, such as regional economic conditions, agricultural outputs, etc. Our study attempts to overcome this limitation with a quasi-experimental design. We make use of the fact that annual fluctuations in the incidence of SDS in China are largely unpredictable, and use a region- and year- fixed effects model to compare the cognitive function of children born in the same region and year but with varying incidence of prenatal SDS exposure because of different gestational timing. This method removes any potential confounders that are region- and year-invariant. Moreover, since SDS are concentrated in the spring months, children born in the same year but different months are exposed to SDS during different periods of fetal development. With a region- and year-fixed effects model, we explore whether for children born in the same region and year, the trimester of exposure yields heterogeneous impacts on children's cognitive function.

3.2 Methods

3.2.1 Data sources and study regions

SDS and meteorological data

SDSs are formally defined by the World Meteorological Organization (WMO) as the result of surface winds raising large quantities of dust into the air and reducing visibility at eye level (1.8 m) to less than 1km.(74) China has published an annual Sand and Dust Weather Almanac (SDSWA) between 2000 and 2012. Following WMO guidance, the China Meteorological Administration defines SDS based on two conditions: 1) visibility <1km and 2) the storm is observed in three or more neighboring national ground meteorological stations (NGMSs). The observed unit of SDS used in this study is days of exposure in each month ("dust days"). "Dust days" is a measure of the intensity of SDS widely used in the previous literature.(88,89) Dust days reported by SDSWA are usually in the form of categories, such as "1-2 days","3-4 days", etc. We adopt the midpoints of that category. For example, if the dust day is "1-2" days, we code it as 1.5 days. To verify the accuracy of SDSWA categories and the appropriateness of using the category midpoints to measure the number of SDS days per month, we also simulated SDS incidence using the Integrated Wind Erosion Model System with data on wind field, soil variables, land use, and vegetation cover (see **Appendix Text 3.1** and **Appendix Figure 3.1** for details).

Data on temperature, humidity, precipitation, and sunshine hours between 2000 and 2012 were obtained from the China Statistical Yearbook and regional Statistical Yearbooks for each city. The data is reported as monthly averages, calculated as the sum of daily average temperature/humidity/precipitation/sunshine divided by the number of days in that month. A full list of the datasets used for meteorological indicators are reported in **Appendix Table 3.1**.

Data on children's cognitive function

Data on children's cognitive function comes from the China Family Panel Studies (CFPS). CFPS is a nationally representative, longitudinal survey launched in 2010 and followed up in 2011, 2012, and 2014. The target sample of CFPS consists of 16,000 households in 25 provinces, municipalities, or autonomous regions in China, representing 95% of the Chinese population. The survey includes questions about the household overall and for each household member. It also collects information on the community in which the household is located. All eligible households and household members are included in the survey.[1]

The CFPS administers two sets of tests to measure children's cognitive function - a mathematics test and a word-recognition test with test items drawn from the standard curriculums in primary and secondary schools to all surveyed children ages 10 and older.(90) The same cognitive tests were first conducted in 2010 and followed up in 2011 and 2014. In every survey round, the respondent is also asked at what age their children began to speak in sentences and at what age their children began counting from one to ten.

Study regions

SDSs are heavily concentrated in the northern part of China and rarely occur in Southern China. Thus we conduct our analysis on the regions located north of the Qinling Mountain-Huaihe River Line, which is typically used as a geographic dividing line between northern and southern China. The CFPS data doesn't release information on county names. To go beyond the level of provinces, we used two types of geographical identifiers: 1) the province where the respondent lives and 2) the dialect zones to which the respondent belongs. We combined the information on the boundaries of these two geographic identifiers and identified 40 province-dialect regions from the 16 provinces located north of the Qinling Mountain-Huaihe River Line. We included all 40 regions in our study. For each region, the number of SDS days per month is calculated as the

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[1] An eligible household refers to an independent economic unit that lives in a residential community, with one or more family members of Chinese nationality. Family members are defined as financially dependent immediate relatives, or non-immediate blood/marital/adoptive relatives who have lived with the household for more than three consecutive months and are financially related to the sampled household. All members over age 9 in a sampled household are interviewed. See more detail in http://www.icpsr.umich.edu/icpsrweb/ICPSR/studies/36524.

mean of the grid points (8km*8km resolution) within the region. Since the meteorological data are provided at the city level, if multiple cities are included in one region, we calculated the meteorological values for that region using a weighted mean of each city. The weight is the actual area of that city included in the region.

3.2.2 Outcome measures

The CFPS mathematics and word-recognition tests end when the individual incorrectly answers three questions in succession. The test scores are defined as the rank of the hardest question a respondent is able to answer correctly. Since the tests were applied to children of various ages, we standardized the test scores by age with the Z-score method. Word and math test scores were widely used in previous studies to measure children's cognitive health. (91,92)

As the cognitive tests only capture cognitive function for children over ten years old, to further explore the impact of SDS on the cognitive function among younger children, we adopt two self-report indicators: First, the age (by month) that a child began speaking a whole sentence, such as "I want to eat"; Second, the age (by month) that a child began counting from one to ten. Speaking capacities and counting skills are commonly used to evaluate the cognitive performance of young children.(93,94)

3.2.3 Sample construction

Figure 3.1 shows the sample constructions for word/math test scores (**Figure 3.1A**), and age to speak a whole sentence/age to count from one to ten (**Figure 3.1B**). As shown in **Figure 3.1A**, we have three exclusion criteria when constructing the sample for word and math test scores: First, among all children aged 10-15 years old, located in the study regions, and with gestational time between 2000-2012 (when SDS data were available), we only keep the record from the first survey if the children were tested in multiple surveys. Second, we excluded children who located in another place when the surveys were conducted than their birth places. This is because we could not identify their moving dates that needed to control for the postnatal exposure to SDS. Moreover, since the children moved, region-fixed effect model would be less effective to remove unobservable region-invariant confounders. Third, we followed previous practice(95) and excluded children who were born preterm (less than 37 weeks or 8.5 months) or overdue (more than 42 weeks or 10 months). Ultimately, we kept 1,236 observations for the analysis.

Figure 3.1B demonstrates how the samples for age to speak a whole sentence/age to count from one to ten are constructed: First, we identified all children's records located in the study regions and with gestational time between 2000-2012. We included children aged 30 to 180 months old when the survey was conducted for speaking and 48 to 180 months for counting, based on the fact that 90% of the children in the sample have started speaking [counting] at 30[48] months. Second, if a child was surveyed for multiple times yet provided inconsistent records, we adopt the report from the earliest survey because recall is likely to be most accurate. Similar as above, we excluded migrants and children born preterm or overdue. A total of 2,693 children are included in the analysis of speaking and 1,951 children for the analysis of counting.

Figure 3. 1 Flow chart of the observations included in the analysis

A) Flow chart of the observations included in the analysis, word and math test scores

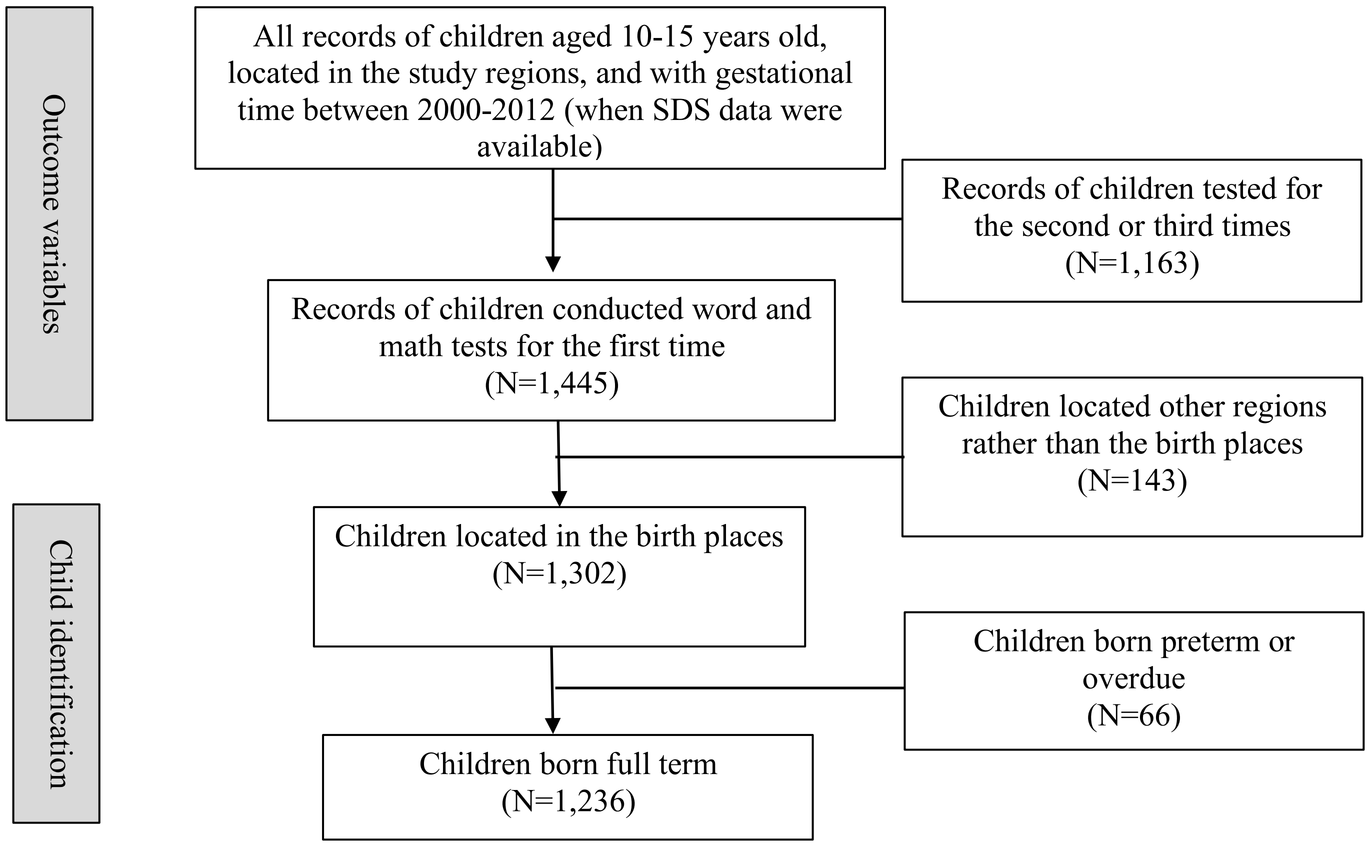
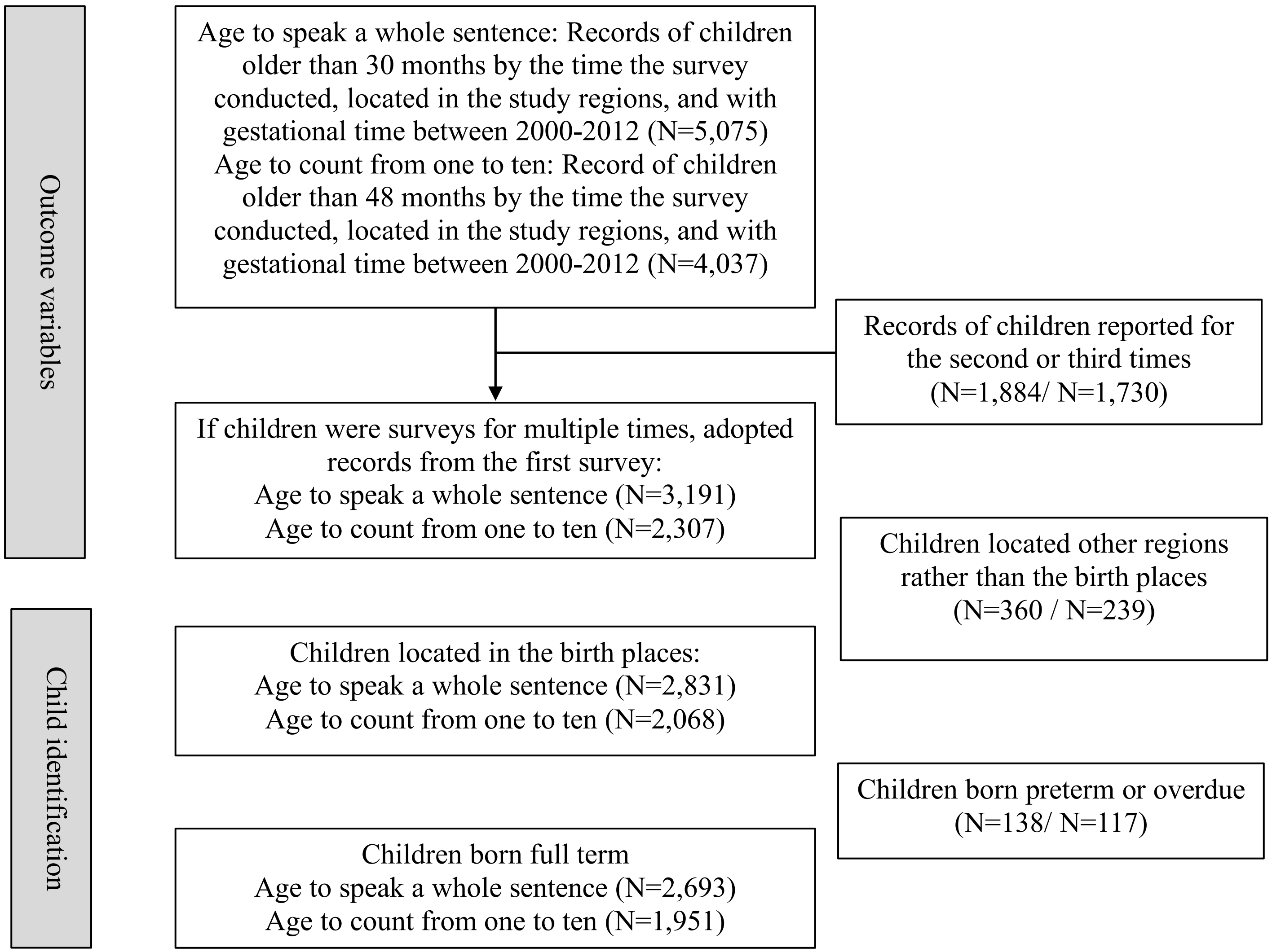


Figure 3. 1 (Continued) Flow chart of the observations included in the analysis

B) Flow chart of the observations included in the analysis, age to speak a whole sentence and age to count from one to ten



3.2.4 Statistical analysis

Overall prenatal exposure to SDS

We analyzed the impact of prenatal SDS exposure on cognitive outcomes with a region- and year-fixed effects model. This model explored the relationship between fluctuations in SDS during gestational period and outcomes, for children born in the same region and year, controlling for a variety of possible confounders.

The model is based on ordinary least square (OLS) regression. As described above, we had four dependent variables, including word test score, math test score, age to begin speaking a whole sentence, and age to begin counting from one to ten. We conducted separate regression for each of these four variables.

The independent variable was the total number of days that the children were exposed to SDS during the gestational period. CFPS provided self-reported data on the date of birth for each child, as well as his/her gestational length.(96) Using this information, we calculated the starting and ending dates of each child's gestational period. Then, we generated the total number of days that the child was exposed to SDS during the gestational period. We divided the incidence of SDS by 10 throughout this paper, so the coefficients of the independent variable represented the changes in outcomes with ten more days of in utero SDS exposure.

We included region- and year-fixed effects in the model to eliminate the impact of unobservable region-invariant and year-invariant confounders. To manage region- and year-fixed effect, we included a dummy for each region and a dummy for each gestational year. Since the gestational period may be spread over two years and SDS is concentrated in the Spring, we treat the child's gestational year as the one that covers the spring. For example, if the gestational period for a child was from July 2002 to April 2003, we considered 2003 the gestational year (t=2003).

We controlled for the following covariates – 1) All indictors in **Table 3.1**, except the days of SDS exposure (the independent variable). Substantial studies showed that child, parent, and household characteristics in **Table 3.1** are significantly associated with children's cognitive development (97,98) and are also potentially associated with prenatal exposure to harmful environmental pollutant, including SDS.(99,100) 2) We controlled for postnatal exposure (within one year after birth) to SDS to eliminate the potential impact of postnatal SDS exposure on children's cognitive development. 3) We also included dummies for child's calendar birth month as the covariates because child's birth month could be associated with both his/her cognitive development (101), as well as the length and timing of prenatal SDS exposure. 4) We included a monthly average of meteorological indicators (temperature, humidity, precipitation, and sunshine hours) during the entire prenatal period. The error terms are assumed to be normally distributed. The standard errors are robust and clustered at the region level.

Since children's ages to begin speaking a whole sentence and to begin counting from one to ten are self-reported data and may suffer from recall bias, we conducted a sensitivity analysis by adding age-fixed effects in the regression. This model allows us to investigate the association between SDS and cognitive outcomes among children interviewed at the same age when the survey was conducted, and born in the same region and year. Moreover, due to data limitations, we cannot identify the amount of in-utero exposure to other pollutants in the analysis. The best data we can obtain regarding the other pollutants is the annual average levels of SO2 and NO2 at the province level since 2003 from the China Statistical Yearbook. We included these two variables in the regression as a sensitivity test and showed the results in appendix.

To evaluate the fitness of linear regression model, we followed the previous practice (102) by plotting the residuals against the independent variable, detecting outliers, and checking R-square. The evaluation process is presented in the Appendix.

Exposure to SDS by gestational month

Our second analysis investigated whether the effects of SDS exposure varied by the gestational period in which the fetus was exposed. We again used a region- and year- fixed effects model to remove the effects of omitted regional and year invariant variables.

Comparing to the model on "*Overall prenatal exposure to SDS*", we replaced the aggregate days of prenatal exposure to SDS with the number of SDS exposures during each gestational month, dummy variables for children's gestational month, and the interaction terms of these two in the regression. For example, if a woman's pregnancy period started from March15th 2005, the first gestational month was March 15th to April 15th 2005. The number of SDS exposure in the first gestational month was the total number of SDS days between March 15th to April 15th in that region at year 2005. As discussed above, we divided the incidence of SDS by 10. The interaction term was the main parameter of interest, which showed the difference in the association between prenatal SDS exposure and children's cognitive function by gestational month. We plotted the coefficients of this interaction term to illustrate how outcomes would change with ten more days of prenatal SDS exposure in each gestational month.

Unadjusted models

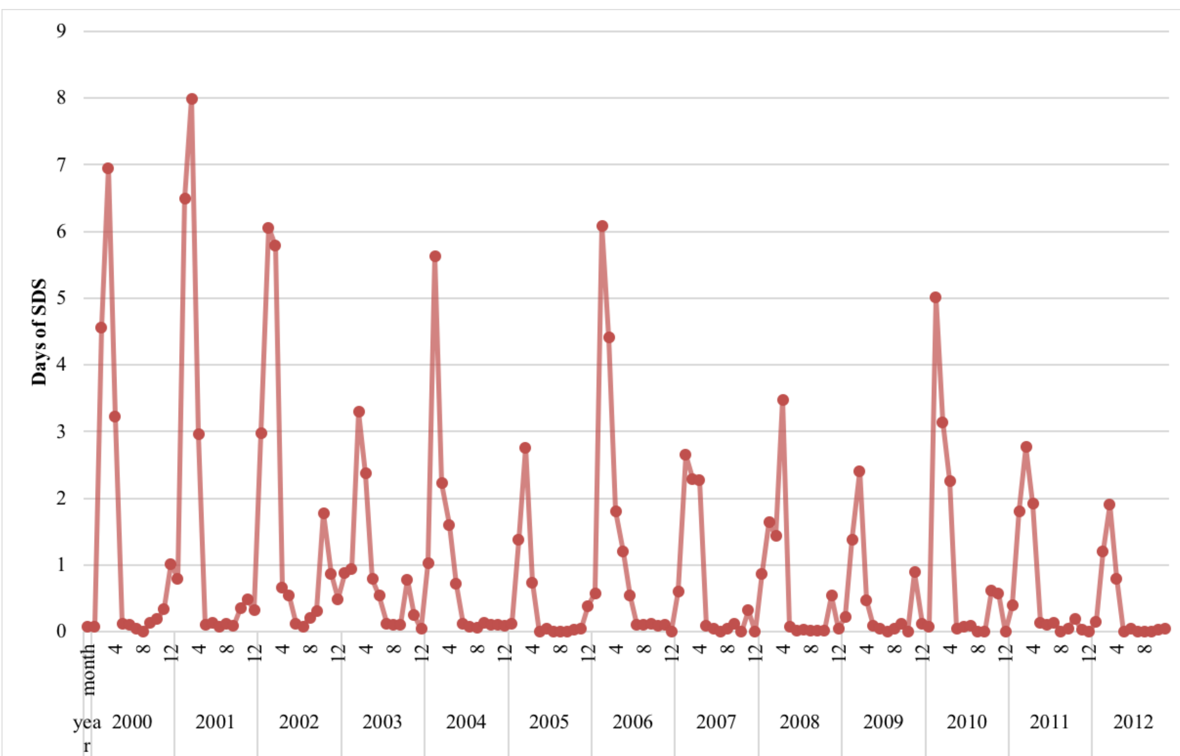
Besides the models adjusting for region- and year-fixed effects and other covariates, we also performed the unadjusted regressions on overall prenatal exposure to SDS and exposure to SDS by gestational month.

3.3 Results

3.3.1 Summary statistics

Figure 3.2 presents the distribution of days of SDS exposure by month between 2000-2012. On average, SDS occurred for 3.0 days in each month during the spring (March, April, May) and 0.2 days in each month for the rest of the year. **Appendix Figure 3.2** shows the distribution of children's prenatal exposure to SDS. The median is 6.0 days and the mean is 6.2 days. The top quintile is 8.4 days and the bottom quintile is 3.1 days.

Figure 3. 2 Days of SDS exposure in the studied regions by month, 2000-2012



Summary statistics for key characteristics of the study sample are presented in **Table 3.1**. We present characteristics of children who had below-median levels of SDS exposure prenatally (less than 6 days) and those who had above-median levels of SDS exposure (6 or more days), in order to explore whether these groups appear to differ in any systematic way other than SDS exposure. Most variables are statistically similar for children with above and below median SDS exposure. SDS exposure is on average 3.36 days for the low-exposure group, significantly lower than the average of 9.87 days in the high SDS exposure group. 48.6%-50.9% percent of the mothers and 57.9% to 59.0% of the fathers possess junior or higher education levels. The mothers are on average 38 years old and the fathers are on average 39 years old. More than 70% of the sample is from a rural area. Compared to children in the below-median exposure group, children in the above-median exposure group appear to be slightly older, more likely to live with mothers, and to live in families with fewer members, more likely to have mothers as agriculture workers, less likely to have an unemployed mother, and more likely to use uncleaned fuel for cooking, yet the differences are small in magnitude.

Table 3. 1 Characteristics of children with above and below-median prenatal sand-dust exposure

	1) Below-median exposure (<6 days)	2) Above-median exposure (>=6 days)	3) P value of the difference between 1) and 2)
Days of SDS exposure	3.37 ±0.05	9.87±0.24	0.00
Children's characteristics			
Age in 2014	9.23±0.15	9.54±0.21	0.02
Gender (% male)	54.6%	52.6%	0.34
Gestational age by month	9.36±0.02	9.38±0.03	0.20
Height-for-age z score in 2014	-0.11±0.12	0.21±0.17	0.55
BMI-for-age z score in 2014	0.17±0.11	0.19±0.13	0.82
Parents' characteristics			
Mother's education level in 2014			
Illiteracy (Not complete primary school)	21.9%	24.8%	0.12
Complete primary school	27.1%	26.6%	0.79
Junior or senior high school	44.4%	43.0%	0.52
College or higher	6.5%	5.6%	0.35
Father's education level in 2014 age to talk a whole sentence/age to count from one to ten			
Illiteracy (Not complete primary school)	11.8%	15.0%	0.03
Complete primary school	29.2%	27.1%	0.29
Junior or senior high school	51.3%	49.3%	0.35
College or higher	7.7%	8.6%	0.42
Mother's age in 2014	37.71±0.33	37.79±0.39	0.77
Father's age in 2014	39.43±0.33	39.58±0.39	0.57
Live together with mother in 2014 (%)	85.4%	89.4%	0.01
Live together with father in 2014 (%)	71.7%	76.9%	0.14
Mother alive in 2014 (%)	99.5%	99.5%	0.97
Father alive in 2014 (%)	99.4%	98.9%	0.23
Maternal employment			
Agriculture workers (%)	33.9%	41.3%	0.00
Non-agriculture workers (%)	15.2%	14.3%	0.53
Unemployed (%)	51.0%	44.5%	0.00
Household's characteristics			
Place of residence (% live in urban)	29.6%	23.7%	0.14
Household income per capita (log)	8.66±0.06	8.63±0.09	0.61
Family size in 2014	5.34±0.09	4.83±0.10	0.00
Cooking fuel			
Uncleaned cooking fuel, including wood, straw, and coal (%)	46.9%	51.6%	0.04
Cleaned cooking fuel, including gas, solar energy, methane, electricity (%)	53.1%	48.4%	0.04
Number of observations	1,923	1,143	

Note:

1. "Below-median exposure" refers to children exposed to SDS for less than six days during the entire prenatal period
2. "Above-median exposure" refers to children exposed to SDS for six days or more during the entire prenatal period
3. The height-for-age z score and BMI-for-age z score calculated according to WHO child growth standards

3.3.2 Overall prenatal exposure to SDS and children's cognitive function

Table 3.2 presents results from the region-and year-fixed effects model. We find that ten additional days of in-utero SDS exposure is associated with a 0.20 standard deviation reduction in word test scores (p=0.009, 95%CI 0.06, 0.35), but find no relationship between SDS exposure and math test scores (p=0.629, -0.19, 0.15). We also find that ten additional days of prenatal SDS exposure delays the age of first speaking whole sentences by 0.04 months (p=0.089, 95%CI -0.00, 0.09) and the age of first counting by 0.14 months (p=0.021, 95%CI 0.03, 0.25). The sensitivity analysis using a region-, year-, and age-fixed effects model (**Appendix Table 3.2**) shows consistent results. The sensitivity analysis including SO2 and NO2 since 2003 also shows consistent results (**Appendix Table 3.3**).

Table 3. 2 The association between overall exposure to SDS in utero and children's cognitive function, with 95% confidence intervals

	Average Effect of SDS	
	Region- and year-fixed effect	**Unadjusted effect**
Math test score (z-score)	-0.02 (-0.19, 0.15)	0.00 (-0.01, 0.02)
Word test score (z-score)	-0.20*** (-0.35, -0.06)	-0.13* (-0.29, 0.03)
Age to start speaking a whole sentence (month)	0.04* (-0.00, 0.09)	0.12*** (0.06, 0.17)
Age to start counting from one to ten (month)	0.14** (0.03, 0.25)	0.19*** (0.06, 0.32)

Note:

1. The incidence of SDS is divided by 10. The coefficients represent the change in outcomes with ten more days of in utero exposure to SDS.
2. 95% confidence intervals are presented in the parentheses
3. The observations are clustered at province-dialect zone level
4. *** represents significance at the 1% level, ** represents significance at 5% level, * represents significance at 10% level

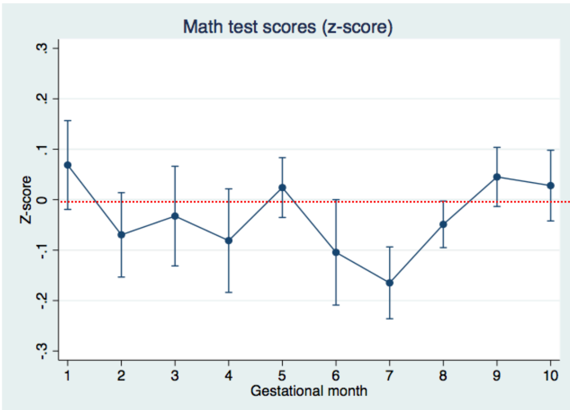
3.3.3 Exposure to SDS by gestational month and children's cognitive function

Figure 3.3 plots the coefficient estimates on the interaction between gestational month and SDS exposure for each outcome. **Table 3.3** presents the coefficients in adjusted and unadjusted form. The figures with math test scores, word test scores, and the age the child began speaking a whole sentence consistently show that exposure to SDS during the 6^{th}, 7^{th} and 8^{th} gestational months is significantly negatively associated with children's cognitive function, suggesting the overall negative association between prenatal SDS exposure and cognitive health demonstrated above is stemming from exposures occurring during the 6^{th}, 7^{th} and 8^{th} month gestation. The same result is also found in the age to begin counting from one to ten during the 6^{th} and 7^{th} gestational months. No association is found for SDS exposure in other gestational months.

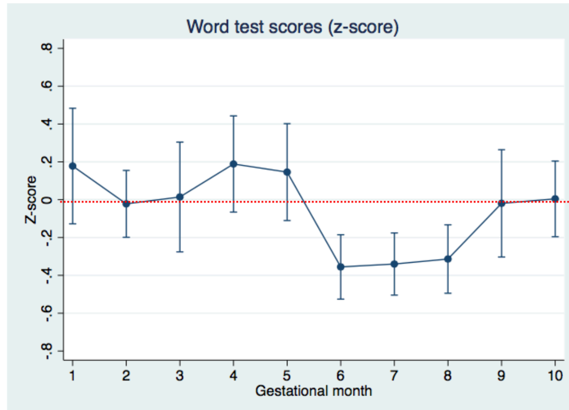
In **Table 3.3**, we present the numerical values of coefficients in **Figure 3.3**, along with the coefficients from unadjusted models. We can see that the adjusted and unadjusted results are similar for all four outcomes. For example, the adjusted results show that ten additional days of SDS exposure in the 7^{th} gestational month is associated with a 0.18 standard deviation (95% CI: 0.10, 0.25) lower math test score, a 0.34 standard deviation (95%CI: 0.18, 0.50) lower word test score, 0.33 (95%CI: 0.07, 0.59) additional months to begin speaking a whole sentence, and 0.20 (95%CI: 0.04, 0.35) additional months to start counting from one to ten. The unadjusted results appear to be quite similar in terms of both the coefficients and the significant levels.

Figure 3. 3 Association between SDS exposure and cognitive health by gestational month of exposure, with 95% confidence intervals (based on region- and year- fixed effect model) $

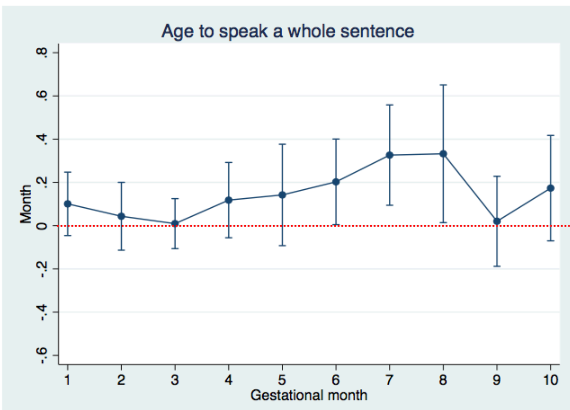
Panel A. Math test score (z-score), n=1,236



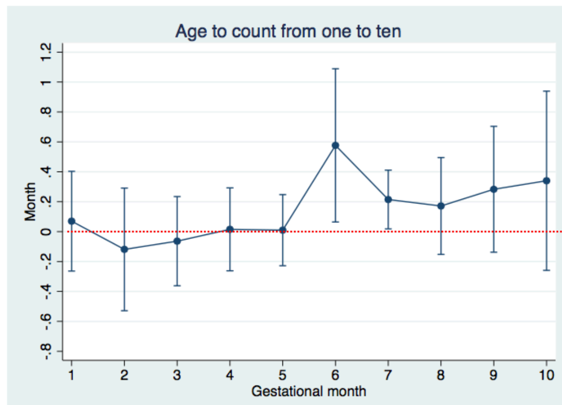
Panel B. Word test score (z-score), n=1,236



Panel C. Age to start speaking a whole sentence (month), n=2,693



Panel D. Age to start counting from one to ten (month), n=1,951



Note:

1. The incidence of SDS is divided by 10. The coefficients represent the change in outcomes with ten more days of in utero exposure to SDS.
2. The observations are clustered at province-dialect zone level
3. Characteristics adjusted: We adjusted for children's characteristics, parents' characteristics, and household's characteristics as shown in Table 3.1. We also adjusted for children's birth months, children's postnatal exposure to SDS, and the monthly average meteorological conditions. We included one dummy variable for each province-dialect zone to control for the regional characteristics and also one dummy variable for each year to control for the year-fixed effect.

Table 3. 3 Effects of SDS exposure in each gestational month on children's cognitive function, unadjusted Vs. adjusted (based on region- and year- fixed effect model)

	Math test score (z score)		Word test score (z score)	
	Unadjusted	**Adjusted**	**Unadjusted**	**Adjusted**
1st month	-0.019	0.070	-0.055	0.178
	(-0.153, 0.115)	(-0.018, 0.158)	(-0.303, 0.193)	(-0.128, 0.485)
2nd month	-0.073	-0.067*	-0.088	-0.020
	(-0.198, 0.052)	(-0.148, 0.014)	(-0.322, 0.146)	(-0.196, 0.156)
3rd month	-0.050	-0.033	-0.024	0.015
	(-0.177, 0.077)	(-0.131, 0.065)	(-0.298, 0.250)	(-0.275, 0.305)
4th month	-0.009	-0.081	0.129	0.189
	(-0.123, 0.106)	(-0.184, 0.022)	(-0.145, 0.403)	(-0.065, 0.443)
5th month	-0.085	0.023	0.147	0.144
	(-0.207, 0.038)	(-0.037, 0.083)	(-0.129, 0.423)	(-0.114, 0.402)
6th month	-0.147*	-0.102**	-0.265**	-0.352***
	(-0.296, 0.002)	(-0.202, -0.002)	(-0.500, -0.031)	(-0.519, -0.185)
7th month	-0.179***	-0.176***	-0.254**	-0.340***
	(-0.302, -0.056)	(-0.246, -0.096)	(-0.466, -0.042)	(-0.504, -0.175)
8th month	-0.057	-0.050**	-0.236*	-0.315***
	(-0.210, 0.096)	(-0.095, -0.005)	(-0.477, 0.005)	(-0.498, -0.132)
9th month	-0.009	0.046	-0.014	-0.020
	(-0.157, 0.139)	(-0.014, 0.106)	(-0.297, 0.268)	(-0.304, 0.264)
10th month	0.009	0.027	-0.069	0.004
	(-0.171, 0.190)	(-0.043, 0.097)	(-0.403, 0.266)	(-0.194, 0.203)

Table 3. 3 (continued) Effects of SDS exposure in each gestational month on children's cognitive function, unadjusted Vs. adjusted (based on region- and year- fixed effect model)

	Age to start speaking a whole sentence (month)		Age to start counting from one to ten (month)	
	Unadjusted	**Adjusted**	**Unadjusted**	**Adjusted**
1st month	0.161*	0.100	0.158	0.068
	(-0.028, 0.351)	(-0.048, 0.248)	(-0.243, 0.559)	(-0.265, 0.401)
2nd month	0.049	0.043	-0.014	-0.123
	(-0.127, 0.226)	(-0.114, 0.200)	(-0.424, 0.397)	(-0.529, 0.284)
3rd month	0.165*	0.009	0.088	-0.060
	(-0.028, 0.358)	(-0.107, 0.125)	(-0.346, 0.523)	(-0.359, 0.239)
4th month	0.109	0.120	0.057	0.016
	(-0.071, 0.289)	(-0.054, 0.294)	(-0.349, 0.464)	(-0.259, 0.292)
5th month	0.097	0.142	0.213	0.013
	(-0.102, 0.297)	(-0.094, 0.377)	(-0.242, 0.669)	(-0.227, 0.253)
6th month	0.212**	0.200**	0.591***	0.575**
	(0.033, 0.391)	(0.006, 0.394)	(0.178, 1.004)	(0.059, 1.091)
7th month	0.266***	0.328***	0.346*	0.197**
	(0.078, 0.453)	(0.071, 0.585)	(-0.009, 0.700)	(0.042, 0.351)
8th month	0.288***	0.325**	0.317	0.170
	(0.081, 0.496)	(0.014, 0.636)	(-0.144, 0.778)	(-0.149, 0.489)
9th month	0.037	0.020	0.422	0.275
	(-0.190, 0.264)	(-0.191, 0.231)	(-0.093, 0.938)	(-0.177, 0.727)
10th month	0.024	0.171	0.244	0.352
	(-0.158, 0.206)	(-0.070, 0.412)	(-0.193, 0.682)	(-0.253, 0.957)

Note:

1. The incidence of SDS is divided by 10. The coefficients represent the change in outcomes with ten more days of in utero exposure to SDS, in a given gestational month.
2. Characteristics adjusted: We adjusted for children's characteristics, parents' characteristics, and household's characteristics as shown in Table 3.1. We also adjusted for children's birth months, children's postnatal exposure to SDS, and the monthly average meteorological conditions. We included one dummy variable for each province-dialect zone to control for the regional characteristics and also one dummy variable for each year to control for the year-fixed effect.

3.4 Discussion

This study found that prenatal exposure to SDS was associated with poorer cognitive outcomes among children. The effect varied by which gestational month the exposure occurred. We found that SDS exposure during the 6th and 7th month gestation is significantly associated with poorer future cognitive function, with consistent results across statistical models. The magnitudes appear to be large – For example, as the SDS exposure increased from the bottom (0.5 days) to the top quintile (4.0 days) during the 7th gestational month, children's math and word test scores reduced by 0.06 SD and 0.12 SD respectively. Their ages to start speaking [start counting] are also delayed by 0.11 months [0.07 months] on average. These findings speak to the general fetal origins hypothesis, which proposes that conditions prevailing during the critical periods of prenatal growth have long-term impacts on developmental health.

Our result well aligns with the previous animal studies showing that fetal brains are easily affected by environmental pollutants because the development of the blood-brain barrier in the fetus is incomplete and fetal brains are sensitive to any pollutant-triggered changes in blood-borne substances.(81–83) Recent human studies have also provided evidence that ambient and indoor pollutants could cross the placenta and damage the fetal brain, likely by inducing inflammation, oxidative stress, and vascular injury.(84–87) A handful of studies also investigated the effects of pollutants by trimesters of exposure, yet the results are inconclusive and potentially biased by confounders.(86,99)

Compared to the previous human studies, one salient strength of this study is that we are able to identify the association between prenatal SDS exposure and children's cognitive function with strong causal inference. As the incidence and intensity of SDS varies greatly by year and season and is hard to predict beforehand, people cannot choose which years to be pregnant to avoid it.

Based on this feature, we adopted a region- and year- fixed effects model to compare children who were prenatal in the same region and year, but with varying incidence of prenatal SDS exposure. In this way, we could effectively remove the impact of unobservable region-and year-specific variables that do not vary over time. The records on each child's gestational time and birth date further allowed us to identify the exposure of SDS in each gestational month and look into the effects of SDS by gestational month. Moreover, our study design also makes use of formalized tests on cognitive assessment and detailed monitoring of multiple potential confounding factors.

This study has several limitations. First, we cannot fully exclude the impact of other pollutants, such as NO2, SO2, and O3, due to lack of data. Although we conducted a sensitivity analysis by including annual average levels of SO2 and NO2 since 2003 in the regression, we acknowledge that the annual data do not capture seasonal variations in SO2 and NO2. Yet numerous articles have documented that these pollutants are highest in winter months and have only minor annual fluctuation, which strongly supports our assumption that the occurrence of SDSs is not correlated with the other pollutants.(103) Moreover, by controlling for the child's birth month, we are comparing the effects of prenatal exposure to SDS among children born in the same month with similar exposure to other pollutants.

Second, the data on the age children began speaking and began counting may suffer from recall bias. To address the issue of recall bias, when the children were surveyed repeatedly with these questions in different survey rounds, we adopted the answers from the first survey. We also conducted a sensitivity analysis that included age-fixed effects, to study the association between SDS and cognitive outcomes among children who were at the same age when the survey was conducted and born in the same region and year.

Third, we cannot fully exclude the effects of indoor pollutants, nor can we control for the pregnant woman's behavioral patterns during SDS. For example, if women were more likely to stay indoors during SDS, they might be less exposed to SDS but more exposed to indoor pollutants, causing the estimated results to change in an unknown direction. To control for potential effects of indoor pollutants, we included the types of cooking fuel in the analysis. We compared the results from regressions with and without the variable for cooking fuel in **Appendix Tables 3.2** and **3.4**. We found the coefficient on SDS exposure to be essentially unchanged across these two specifications and found the coefficients on cooking fuel to be insignificant. We also included a sensitivity analysis with the interaction term of cooking fuel and in-utero SDS exposure (**Appendix Table 3.5**). The coefficients on the interaction terms are not significant, indicating the associations of in-utero SDS exposure and children's cognitive function did not have a statistical difference by the types of cooking fuel used in the household. However, this method suffered from the following problems: 1) CFPS only reported the types of cooking fuel used at the time the surveys were conducted, which could differ from the type of cooking fuel used during the woman's pregnancy and 2) the types of cooking fuel cannot fully represent the effects of indoor pollutants.

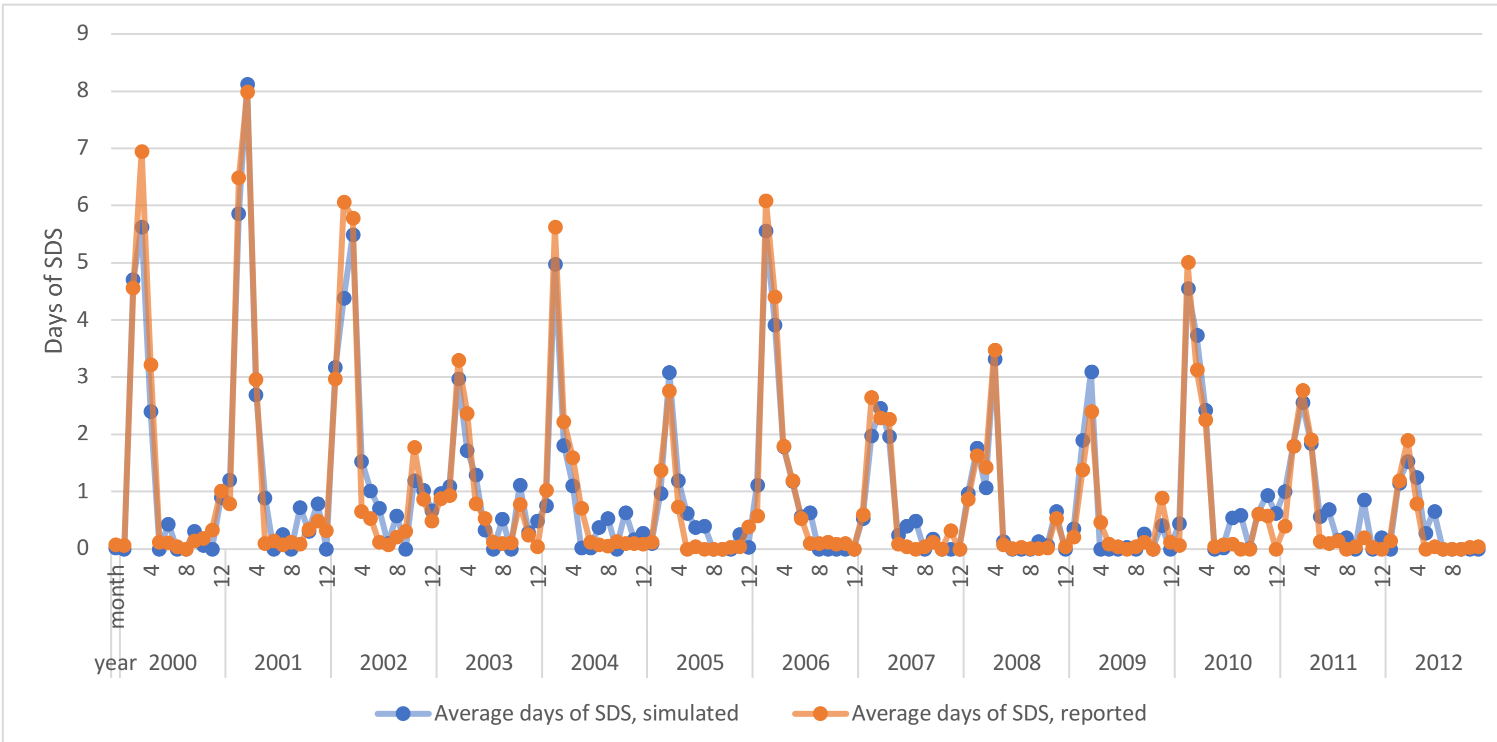
Fourth, we cannot exclude culling from our study. The less healthy babies could have possibly died prenatally or during infancy before being able to appear in the survey. This could lead us to underestimate the association between SDS exposure and cognitive function. Fifth, we cannot fully exclude migrants from the analysis. Pregnant mothers may choose to temporarily move out to avoid SDS exposure and move back in after it was over. The migrants may not be random and may systematically affect our results in an unknown direction. Sixth, we cannot tell whether the effects of SDS are generalizable to children outside of our sample (based on the exclusion criteria in **Figure 3.1A** and **3.1B**). Seventh, we cannot test the mechanisms by which the pollutants may affect children's cognitive function. Although previous animal or human studies have provided some evidence showing that inhaled air pollutants during pregnancy would affect the development of fetus's central nervous system, none of the studies were on SDS specifically. Finally, the strong winds or the dry soil surfaces, which are two necessary conditions for the occurrence of SDS, may affect maternal and child health via other channels, such as reducing food productivity, triggering infectious diseases, influencing electricity and water supply, etc. Despite these limitations, our study is the first to look at the effects of prenatal SDS exposure on children's cognitive function. Our results suggest that in-utero exposure to SDS could have long-lasting adverse effects on children's cognitive development, particularly when the exposure occurred during the 6^{th} and 7^{th} gestational months. Although this study could provide strong causal inference, more research is needed to replicate these results and identify the short- and long-term effects of in-utero exposure to SDS on children's health. It is also important for more clinical evidence to be generated on the mechanisms behind the findings.

Appendix for Chapter 3

Appendix Text 3.1 Simulation of SDS data

To verify the accuracy of the reported SDS, we simulate SDS incidence with Integrated Wind Erosion Model System (IWEMS). IWEMS is widely applied to model the incidence of dust storms in northeast Asia.(104) We obtain the variables required by the IWEMS from the following sources: Wind field datasets are from National Centers for Environmental Prediction and National Center for Atmospheric Research (NCEP/NCAR) which are updated every six hours with a spatial resolution of 2.5°*2.5°; Soil variables are obtained from Harmonized World Soil Database with a map scale of 1:1,000,000; Land use are obtained from the Dara Sharing Infrastructure of Earth System Science with a map scale of 1:100,000 in 2000; The monthly vegetation cover is from the normalized deviation vegetation index (NDVI) with a spatial resolution of 8km*8km. We retrieve the simulated SDS incidence from the IWEMS simulation. Since the IWEMS cannot yield visibility as used for SDS classification, we follow the previous study by Mao Rui et al. and chose the surface dust concentration of 2mg m^{-3} as the threshold for a SDS to occur.(105) For a given grid point, when the simulated daily dust concentration near the surface exceeded 2 mg m^{-3}, a SDS day is set to have occurred at this grid point. We sum up the simulated days of SDS exposure in each month. For each grid point, we compare the simulated SDS days by months with the reported SDS categories. We find that 88.2% of the simulated values fall in the right reported categories, which strongly supports the accuracy of the reported SDS. Appendix Figure 3.1 presents the reported and simulated average days of SDS exposure in each month between 2000 and 2012 in our studied regions. The figure demonstrates that SDSs are heavily concentrated in the spring months, and that the incidence varies greatly by year.

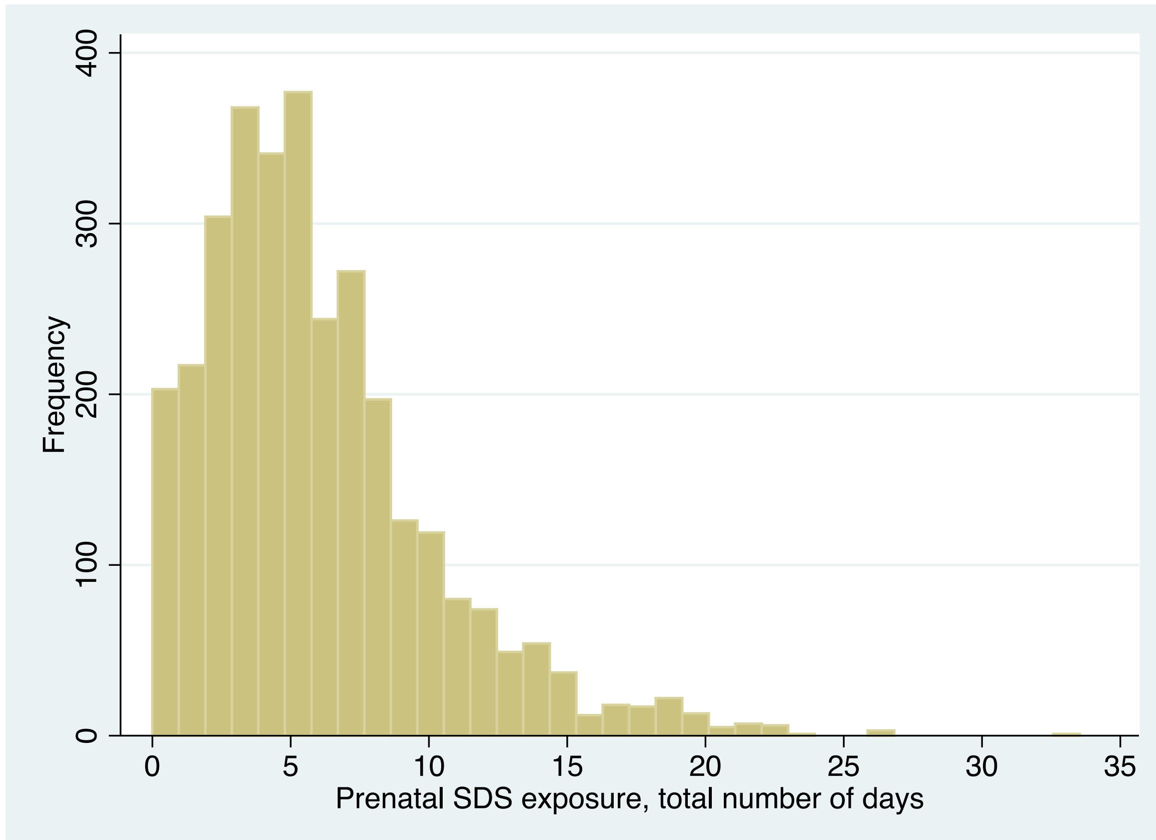
Appendix Figure 3.1 Average days of SDS exposure in the studied regions by month, 2000-2012



Appendix Table 3.1 Data sources of meteorological indicators

Source	**Year**	**Link**
China Statistical Yearbook	2000-2012	http://www.stats.gov.cn/tjsj/ndsj/
Beijing Statistical Yearbook	2000-2012	http://nianjian.xiaze.com/info/bjtjnj.html
Tianjin Statistical Yearbook	2002-2012	http://www.stats-tj.gov.cn/Category_29/Index.aspx
Tianjin Statistical Yearbook	2000-2001	http://nianjian.xiaze.com/info/tianjintongjinianjian.html
Hebei Rural Statistical Yearbook	2000-2012	http://www.yearbookchina.com/navisearch-2-0-3-1-河北省-0.html
Xingtai Statistical Yearbook	2000-2012	https://www.shujuku.org/category/hebei-statistical-yearbook/
Tangshan Statistical Yearbook	2000-2012	https://www.shujuku.org/category/hebei-statistical-yearbook/
Shijiazhuang Statistical Yearbook	2000-2012	https://www.shujuku.org/category/hebei-statistical-yearbook/
Qinhuangdao Statistical Yearbook	2000-2012	https://www.shujuku.org/category/hebei-statistical-yearbook/
Langfang Statistical Yearbook	2000-2012	https://www.shujuku.org/category/hebei-statistical-yearbook/
Hengshui Statistical Yearbook	2000-2012	https://www.shujuku.org/category/hebei-statistical-yearbook/
Chengde Statistical Yearbook	2000-2012	https://www.shujuku.org/category/hebei-statistical-yearbook/
Cangzhou Statistical Yearbook	2000-2012	https://www.shujuku.org/category/hebei-statistical-yearbook/
Handan Statistical Yearbook	2000-2012	https://www.shujuku.org/category/hebei-statistical-yearbook/
Shanxi Statistical Yearbook	2000-2012	http://nianjian.xiaze.com/info/shanxitongjinianjian.html
Liaoning Statistical Yearbook	2000-2012	http://www.cnstats.org/tjnj/2013/lnlntjnj2000-kqz.html
Jilin Statistical Yearbook	2000-2012	http://nianjian.xiaze.com/info/jilintongjinianjian.html
Heilongjiang Statistical Yearbook	2000-2012	http://www.cnstats.org/tjnj/2013/hljhljtjnj2000-aga.html
Shandong Statistical Yearbook	2001-2012	http://www.stats-sd.gov.cn/col/col211/index.html
Shandong Statistical Yearbook	2000	http://nianjian.xiaze.com/info/sdtjnj.html
Henan Statistical Yearbook	2000-2012	http://www.tjcn.org/tjnjsy/dq/28195.html
Shanxi Statistical Yearbook	2000-2012	http://nianjian.xiaze.com/info/shanxitongjinianjian.html
Gansu Statistical Yearbook	2000-2012	http://nianjian.xiaze.com/info/gansufazhannianjian.html

Appendix Figure 3.2 Distribution of total number of days of prenatal SDS exposure



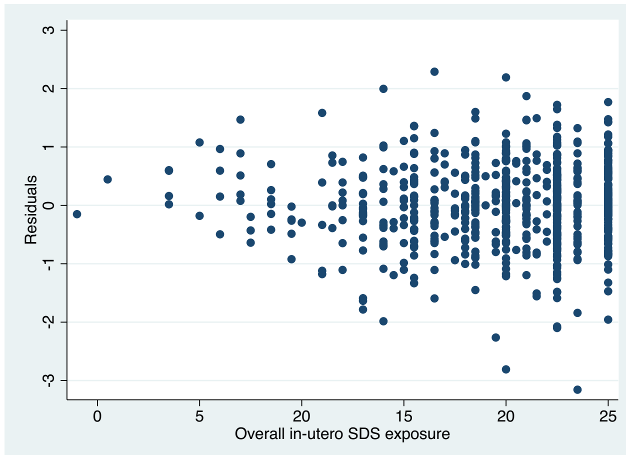
Appendix Table 3.2 The association between overall exposure to SDS in utero and children's cognitive function, with 95% confidence intervals, region-, year- and age-fixed effect

	Region- year-, and age-fixed effect
Math test score (z-score)	-0.02 (-0.20, 0.16)
Word test score (z-score)	-0.21*** (-0.36, -0.06)
Age to start speaking a whole sentence (month)	0.06* (-0.00, 0.11)
Age to start counting from one to ten (month)	0.11** (0.01, 0.21)

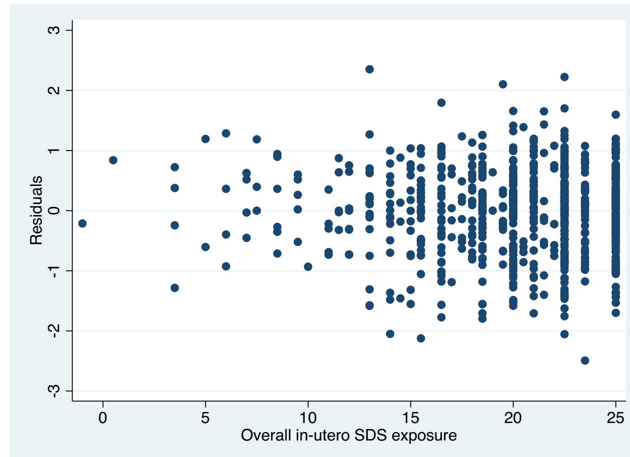
Appendix Text 3.2 Evaluation of the fitness of linear regression model

1) Residual plot from regressing overall exposure to SDS in utero and children's cognitive function, region-, year- and age-fixed effect

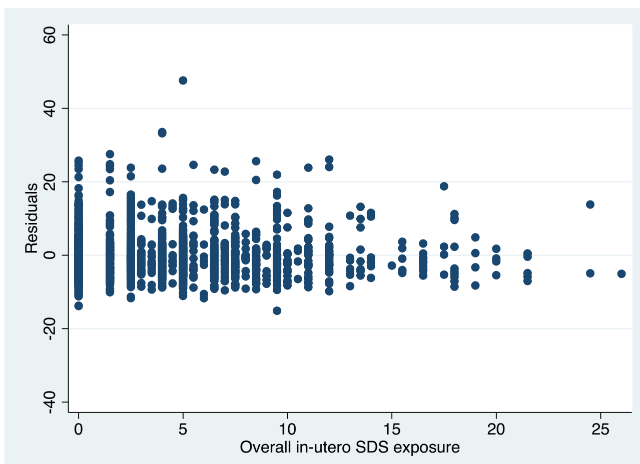
Panel A. Math test score (z-score), n=1,236



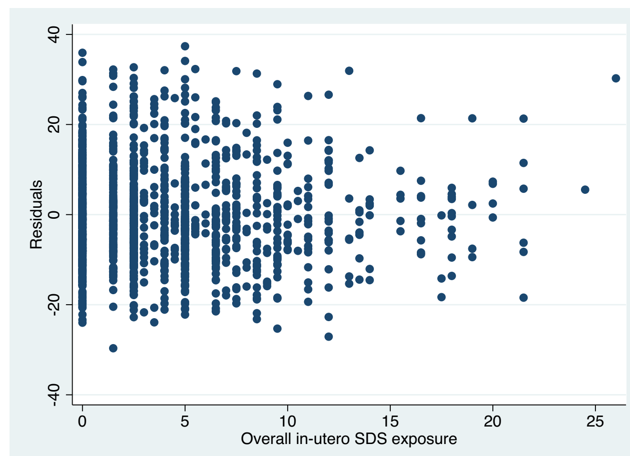
Panel B. Word test score (z-score), n=1,236



Panel C. Age to start speaking a whole sentence (month), n=2,693



Panel D. Age to start counting from one to ten (month), n=1,951



Appendix Text 3.2 (Continued) Evaluation of the fitness of linear regression model

2) Outlier detection

We adopted Nick Cox's extremes STATA command to detect outliners for in-utero SDS exposure, word test score, math test score, age to start speaking a whole sentence, and age to start counting from one to ten. We didn't detect any outliers.

3) R-squares for the regressions adjusted with region- and year- fixed effect in Table 3.2

	R-square
Math test score (z-score)	0.35
Word test score (z-score)	0.27
Age to start speaking a whole sentence (month)	0.24
Age to start counting from one to ten (month)	0.26

Appendix Table 3.3 The association between overall exposure to SDS in utero and children's cognitive function, with 95% confidence intervals, including variables for SO2 and NO2 since 2003

	Region- year-, and age-fixed effect
Math test score (z-score)	0.02 (-0.04, 0.08)
Word test score (z-score)	-0.29*** (-0.42, -0.16)
Age to start speaking a whole sentence (month)	0.14*** (0.08, 0.20)
Age to start counting from one to ten (month)	0.11* (-0.01, 0.23)

Appendix Table 3.4 The association between overall exposure to SDS in utero and children's cognitive function, with 95% confidence intervals, region-, year- and age-fixed effect, without the variable for cooking fuel

	Region- year-, and age-fixed effect, without the variable for cooking fuel
Math test score (z-score)	-0.02 (-0.19, 0.15)
Word test score (z-score)	-0.20*** (-0.35, -0.06)
Age to start speaking a whole sentence (month)	0.05* (-0.00, 0.10)
Age to start counting from one to ten (month)	0.12** (0.03, 0.21)

Appendix Table 3.5 The association between overall exposure to SDS in utero and children's cognitive function, with 95% confidence intervals, region-, year- and age-fixed effect, with the interaction term of cooking fuel and in-utero SDS exposure

	Coefficients on in-utero SDS exposure	**Coefficients on the interaction term**
Math test score (z-score)	-0.04	0.07
	(-0.16, 0.08)	(-0.17, 0.32)
Word test score (z-score)	-0.18**	0.04
	(-0.28, -0.08)	(-0.08, 0.16)
Age to start speaking a whole sentence (month)	0.05*	0.02
	(-0.00, 0.10)	(-0.09, 0.14)
Age to start counting from one to ten (month)	0.13**	-0.07
	(0.02, 0.24)	(-0.24, 0.10)

Conclusion

Childhood is a most critical stage presenting the preceding a unique opportunity to lay the foundation for healthy development.(106) The multifaceted feature of child health has been well recognized. In the traditional framework, the determinants of child heath are categorized at child, mother, household, and community levels.(107–110) The first two chapters of these thesis analyzed the impact of three community-level determinants on child health, which are socioeconomic factors, health policy, and health program.

In the first two chapters, we paid special attention on socioeconomic (SES) inequalities in child health could impose severe challenge of "equity from the start" proposed by the World Health Organization Commission on Social Determinants of Health, and place the children in poor families in a vicious circle of poverty – Poorer children tend to be less healthy and could earn less when they enter.(111,112) According to UNICEF, investment in child health is a highly cost-effective strategy that could generate substantial economic return and also perform as an entry point to break the "vicious circle of poverty" and reduce disparity.(113)

Beyond the factors involved in the traditional framework, the importance of environmental compartments on human health has been increasingly recognized. Environmental factors are included in more and more recently developed conceptual frameworks.(114–117) In this third chapter, we presented the readers with the significant influence of environmental factors on child health and provided the stakeholders with a new perspective on how to improve child health.

Summary of findings

Chapters 1 demonstrate that the introduction of user–fee–removal policy in Jamaica immediately increased children's healthcare utilization, and the utilization remained high in the medium–to–

long–term since it removes financial barrier to access healthcare. We also found that the implications of short-term and the medium-to-long-term results appear to have different equity impact: In the short-term (within one year after the introduction of user-fee-removal policy), the utilization gap between the rich and the poor enlarged due to the faster increase in healthcare utilization among children not in poverty compared to children in poverty. This is probably because that wealthier households are better at receiving information about new policies and tend to be quicker in changing their behavior in the short–term. However, in the medium– to long–term (1-5 years after the) introduction of user-fee-removal policy, the utilization gap decreased rapidly as the utilization by children in poverty increased at a faster pace than non–poor between 2008 and 2012. This finding suggests that while conducting equity analysis, one should pay special attention to the study period, because various lengths of studies could produce different results.

Besides the effects of health policy, we further involve the cost part into the study in Chapter 2 to explore the impact of YYB program on children's stunting status in China, as well as its equity impact. We found that the estimated costs to avert a stunting case would vary substantially by province, poverty status, delivery method, and coverage of YYB program, from as low as ¥800 (Chongqing province) to as high as ¥23,000 (Jilin province). Chongqing, Jiangxi, Sichuan, Guangdong, and Guangxi would generally present a lower cost to avert a stunting case; while Anhui, Gansu, and Jilin would present higher costs. Moreover, in most provinces, the costs to avert a stunting case would be cheaper among children living in poverty, pointing to both the efficient and pro-poor potential of YYB rollout in China. With limited financial resources and the government aiming at maximizing health gains in the populations, the provinces showing a lower cost to avert a stunting case would be prioritized.

As child health is multi-dimensional, we expand our study to the factors beyond health sector in Chapter 3 by examining how prenatal exposure to SDS affects children's cognitive development using nationally representative data from China. We find that countries experiencing SDSs should have more policies in place to protect exposure among pregnant women, particularly in the 6th and 7th gestational months, to generate long-lasting benefits for the cognitive function of the next generation. Further studies are needed to track the health effects of prenatal SDSs exposure in longer terms, such as what would happen when the affected children entered adolescence, adulthood, and old age.

Policy implications

My thesis has two essential implications: First, the same policies could generate very different effects and cost-effectiveness on various populations and during different periods. Second, factors beyond health sector may have large impact on child health as well. Based on these implications, we suggest the interventions targeting child health should take the following factors into consideration, including 1) the short- and long- effect sizes of interventions, as well as equity impact among various population, 2) the cost-effectiveness to apply the interventions, 3) the feasibility to coordinate with other sectors, such as environmental sector, to improve child health.

Future research

There are several limitations in my thesis research to be addressed in the future. With the model presented in Chapter 1, we only discuss how much the healthcare utilization increased after launch of user-fee-removal policy, yet we didn't reveal the causes of it – whether it was due to the release of unmet demand or moral hazard? It is possible that when health services become free or inexpensive, people may tend to overuse them, leading to wastage of health resources. Whether this happens in the case of Jamaica and the extent to which it changes people's behavior is unclear. Similarly, in Chapter 3, although we could confidently tell the effects of prenatal exposure to SDS on children's cognitive development, we are unable to uncover the mechanism behind the findings. For example, we are unclear what type of the pollutants may affect children's cognitive function and how the impact occurs. Chapter 2 may suffer from challenges on the assumptions of the model, such as linearity relationship between road density and transportation cost, no variations adherence and acceptability rates, no economy of scale, etc. We call for future work to identify mechanisms behind the findings, such as the scientific evidence of how pollutant affect cognitive development, the reasons for interventions to yield various impact among different population, causes of increased healthcare utilization, etc. We also call for more reliable data and more realistic assumptions to be used in future studies.

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