Scholar Commons
USF University of South Florida

University of South Florida
Scholar Commons

Graduate Theses and Dissertations | Graduate School

July 2017

Essays in Health Economics

Olga Petrova
University of South Florida, olgapetrova@mail.usf.edu

Follow this and additional works at: http://scholarcommons.usf.edu/etd

 Part of the Economics Commons

Scholar Commons Citation
Petrova, Olga, "Essays in Health Economics" (2017). *Graduate Theses and Dissertations.*
http://scholarcommons.usf.edu/etd/6927

This Dissertation is brought to you for free and open access by the Graduate School at Scholar Commons. It has been accepted for inclusion in Graduate Theses and Dissertations by an authorized administrator of Scholar Commons. For more information, please contact scholarcommons@usf.edu.

Essays in Health Economics

by

Olga Petrova

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
Department of Economics
College of Arts and Sciences
University of South Florida

Major Professor: Gabriel Picone, Ph.D.
Bradley Kamp, Ph.D.
Troy Quast, Ph.D.
Xin Jin, Ph.D.

Date of Approval:
June 29, 2017

Keywords: early-life health, birth outcomes, antimalarial interventions, medical marijuana laws

Copyright © 2017, Olga Petrova

DEDICATION

This work is dedicated to Joseph Steven Coleman and a group of economists who wished to remain unknown.

ACKNOWLEDGMENTS

I would like to express my gratitude to my Major Professor, Gabriel Picone, for his guidance, support, and invaluable feedback. I thank Bradley Kamp, Troy Quast, and Xin Jin for taking the time to serve on my Doctoral Dissertation Committee, review my research, and provide expert advice. I am grateful to Delroy Hunter for taking on the role of the Doctoral Dissertation Defense Chair.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Over the past two decades, a growing body of literature within health economics has provided evidence of the impact of fetal conditions on individual's health and economic outcomes over the entire life course. This dissertation contributes to the field of health economics by investigating the effects of two distinct types of public policies, antimalarial interventions in sub-Saharan Africa and medical marijuana laws in the United States, on early-life health.

Chapter 1 adds to the increased understanding of the impact of *in utero* exposure to large-scale interventions to combat endemic diseases by examining the effects of antimalarial interventions aimed at preventing and controlling malaria in pregnancy on birth outcomes. Since the year 2000, a coordinated international effort against malaria has led to a significant scale-up of intervention coverage across sub-Saharan Africa. One of the objectives of this undertaking was to improve maternal and early-life health. This chapter investigates the effect of access to malaria prevention and control measures, including insecticide-treated nets, intermittent preventive treatment in pregnancy, indoor residual spraying, and artemisinin-based combination therapy, on birth weight. I exploit the geographic and time variation in the rollout of antimalarial interventions in sub-Saharan Africa across regions with different levels of initial malaria prevalence to analyze 277,245 live births in 22 countries from 2000 to 2013 in a continuous difference-in-differences estimation framework and find that the diffusion of intermittent preventive treatment among pregnant women contributed to the reduction of low birth weight incidence in sub-Saharan Africa. I do not find other antimalarial interventions to be associated with significant improvements in birth outcomes.

Chapter 2 provides an investigation focused on examining the impact of medical marijuana laws in the United States on birth outcomes. As of June 2017, medical marijuana laws which liberalize the cultivation, possession, and use of cannabis for allowable medical purposes have been adopted by 29 states and the District of Columbia. The expansion of state-level legislation allowing for medical marijuana use has fueled an ongoing debate regarding drug policy. Despite a growing interest in investigating and quantifying both direct and indirect effects of marijuana liberalization policies, little is known about how they affect early-life health. Using data on the entire universe of births in the U.S. between 1990 and 2013 and a difference-in-differences research design, I find no evidence to support the hypothesis that medical marijuana laws have a negative impact on birth weight and gestation, however I also find that medical marijuana laws are associated with reductions in Apgar scores.

CHAPTER 1:

ANTIMALARIAL INTERVENTIONS AND EARLY-LIFE HEALTH:

EVIDENCE FROM SCALE-UP IN SUB-SAHARAN AFRICA

1.1 INTRODUCTION

A growing literature in health economics and related fields provides evidence of the nine months spent *in utero* as a critical period that affects individual's health and economic outcomes over the entire life course. Numerous papers substantiate that intrauterine shocks can have significant, long-lasting consequences (Currie and Vogl, 2013, Almond and Currie, 2011a, 2011b, Currie, 2011, Currie and Rossin-Slater, 2015 provide an overview of this literature). Indicators of neonatal health such as birth weight have been found to predict many future outcomes including earnings, employment, test scores, educational attainment, family formation, crime, as well as health outcomes of next generations. While much of this literature focuses on developed countries, most recent studies suggest that health *in utero* and in early life may be an even more significant determinant of adult outcomes in developing countries due to more frequent and more numerous health shocks as well as limited remedial capacity. At the same time, estimating the effects of fetal conditions on various outcomes may be particularly challenging in developing countries due to large mortality effects. To the extent that variation in later-life outcomes can be explained by early-life health, these findings offer additional justification for policies aimed at improving maternal and neonatal health.

In the economic literature, short- and long-run effects of fetal shocks have been examined in a variety of contexts. Numerous studies have used catastrophic events such as famines, natural disasters, nuclear accidents, armed conflict, or terrorist attacks as sources of variation in *in utero* conditions to study their effects on both health and non-health outcomes (e.g. Chen and Zhou, 2007; Almond et al., 2010; Lindeboom et al., 2010; Torche, 2011; Simeonova, 2011; Currie and Rossin-Slater, 2013; Banerjee et al., 2007; Almond, Edlund and Palme, 2009; Black et al., 2014; Mansour and Rees, 2012; Lauderdale, 2006; Camacho, 2008; Currie and Schwandt, 2016). Other papers have investigated more moderate fetal shocks such as tax hikes, strikes, or Ramadan observance (e.g. Lien and Evans, 2005(a), 2005(b); Almond and Mazumder, 2011). A number of studies have focused on the effects of fetal and early-life disease exposure, including both endemic and non-endemic diseases in settings with both increases and decreases in incidence due to availability of new treatments, pandemics, or large-scale eradication campaigns (e.g. Almond, 2006; Kelly, 2011; Venkataramani, 2012; Bhalotra and Venkataramani, 2011; Bleakley, 2007, 2010; Cutler et al., 2010; Lucas, 2010; Barreca, 2010; Lucas and Wilson, 2013; Miguel and Kremer, 2004; Apouey et al., 2017). Many of these papers specifically explore the effect of fetal shocks on birth weight (e.g. Torche, 2011; Simeonova, 2011; Currie and Rossin-Slater, 2013; Lauderdale, 2006; Camacho, 2008; Lien and Evans, 2005(a), 2005(b); Mansour and Rees, 2012).

Short- and long-run effects of malaria have been an important focus of the fetal origins literature. The dramatic scale-up of antimalarial interventions in Africa since the year 2000 has increased the importance of accurate estimations of the impact on malaria epidemiology and burden. Effects of malaria and antimalarial interventions have been previously studied by examining eradication campaigns in a difference-in-differences framework using variation in initial disease prevalence for identification (e.g. Bleakley, 2010; Cutler et al., 2010; Lucas, 2010;

Venkataramani, 2012). However, both duration and intensity of malaria control measures may have significant impact on the interpretation of the effects and may explain heterogeneous results across various geographical settings. Thus, the effects of more modest decreases in malaria incidence, such as those achieved in sub-Saharan Africa, likely differ from the effects of a sustained eradication of malaria.

Several recent papers have investigated the effects of antimalarial interventions in sub-Saharan Africa on mortality and fertility (Wilde et al., 2017), anemia (Apouey et al., 2017) and education (Kuecken et al., 2015). However, their impact on early life health has been studied less.

The present study aims at contributing to the fetal origins literature – and specifically to the growing body of evidence of the effect of *in utero* exposure to large-scale interventions to combat endemic diseases – by examining the effects of antimalarial interventions aimed at preventing and controlling malaria in pregnancy on birth outcomes. Current knowledge on the nature and determinants of changing malaria endemicity in sub-Saharan Africa and the effects of control programs on various outcomes beyond simple measures of disease transmission risk and mortality remains weak (Eisele et al., 2012). In recent years, many comprehensive reviews have highlighted various aspects of the epidemiology and burden of malaria in pregnancy but few have evaluated malaria control effectiveness under routine conditions. A large number of randomized controlled trials in sub-Saharan Africa have demonstrated that malaria prevention in pregnancy through intermittent preventive treatment in pregnancy with sulfadoxine-pyrimethamine (IPTp-SP) and insecticide treated bed nets (ITNs) significantly reduces the prevalence of low birth weight (LBW) by as much as 43% (Desai et al., 2007). However, the extent to which the protection observed in such trials can be replicated in the context of targeted

campaigns or a routine health system is uncertain, as assessment of the effectiveness of malaria prevention in pregnancy under real-world conditions has been limited.

Related to the present chapter, an epidemiological study by Eisele et al. (2012) analyzes 26 national cross-sectional datasets and finds an association between the exposure to full malaria prevention in pregnancy through IPTp or ITNs and a 21% reduction in the likelihood of LBW in women in their first or second pregnancy, however concerns about whether this relationship is causal remain.[1] This chapter tries to alleviate these limitations by taking advantage of geographic and time variation in malaria control coverage across regions with different starting (pre-intervention) malaria endemicity in a continuous difference-in-differences estimation framework in order to investigate to what extent the improvements in birth outcomes are specifically attributable to antimalarial interventions. Identifying the effects of interventions in this framework would lend credence to a causal interpretation of earlier findings and, more broadly, contribute to the body of knowledge on the efficacy of interventions designed to help children reach their full potential.

The outline of this chapter is as follows. Section 1.2 provides background on malaria control in Africa and an overview of empirical evidence on the effect of malaria in pregnancy and the benefits of antimalarial interventions. Section 1.3 presents the data and some descriptive statistics. Section 1.4 discusses the empirical strategy and the identification assumptions. The

[1] Eisele et al. (2012) use the MatchIt procedure in R to match newborns by survey dataset and by their mother's exposure to dichotomous observables, then use lme4 package in R to fit a logistic random-effects generalized linear model to assess the association between exposure to malaria prevention during pregnancy and birth outcomes, with the matching strata included as random effects. This identification strategy raises two concerns. First, the main malaria prevalence measure used in this chapter, PfPR among children aged two to ten in 2007, seems more likely to be an outcome. That is, it would seem reasonable to expect that regions with high ITN and IPTp use during the study period (2000–2010) would have a lower PfPR as a result of their high take-up levels, all else constant. Second, Eisele et al. match newborns on a number of variables which are associated with better access to malaria prevention and health status at birth, including those which are not determinants of birth outcomes but are likely outcome measures themselves, for example indicator for at least one neonatal tetanus vaccination. Thus, estimated effects may be biased.

main results, as well as the specification checks are reported in Section 1.5. Section 1.6 concludes.

1.2 BACKGROUND

1.2.1 Malaria Control in Africa between 2000 and 2015

Malaria remains one of the main public health problems in sub-Saharan Africa, where during 2013, an estimated 128 million people were infected with *Plasmodium falciparum*, a malaria parasite, at any one time (WHO, 2014). The region continues to carry a disproportionately high share of the global malaria burden. According to the latest estimates from WHO, in 2015, sub-Saharan Africa accounted for most global cases of malaria (188 million (88%) out of 214 million cases) and most malaria deaths (394,000 (90%) of 438,000 deaths) (WHO, 2015).

Since the year 2000, international efforts to combat malaria in sub-Saharan Africa, largely driven by the Roll Back Malaria initiative and the broader development agenda around the United Nations Millennium Development Goals (MDGs), have achieved an approximately twentyfold increase in malaria financing. This enabled widespread, although highly uneven, scale-up of coverage of ITNs, indoor residual spraying (IRS), IPTp, and prompt treatment of clinical malaria cases with artemisinin-based combination therapy (ACT).

Vector control is the primary means to prevent and reduce malaria transmission. It targets the mosquitoes capable of transmitting malaria parasites and has been shown to effectively reduce or interrupt malaria transmission when coverage is sufficiently high. The two core vector control measures are ITNs and IRS. ITNs provide personal protection from mosquito bites by forming a physical barrier over a person sleeping under them. ITNs reduce human-vector contact not only by physically excluding vector mosquitoes, but also by repelling them or killing them if

they land on the net. IRS is the most effective way to rapidly reduce malaria transmission. It kills the mosquito vector, remains effective for 3–6 months, depending on the insecticide formulation used and the type of surface on which it is sprayed, and requires at least 80% of houses in targeted areas to be sprayed for maximum effect. In 2014, an estimated 56% of the population in sub-Saharan Africa had access to an ITN, compared to less than 2% in 2000, and approximately 6% of the population at risk of malaria in Africa lived in households protected by IRS. The estimated proportion of the population for whom any form of vector control had been made available in sub-Saharan Africa increased from 2% in 2000 to 59% in 2014 (WHO, 2015).

Use of antimalarial drugs both for prevention and treatment is another important component of malaria control. Chemoprevention of malaria is based on the use of antimalarial drugs given in treatment doses at predefined intervals, particularly to pregnant women and children, and constitutes another important component of antimalarial interventions. In 2014, an estimated 52% of eligible pregnant women received at least one dose of IPTp, compared to less than 5% in 2003 (WHO, 2015). Adoption and implementation of chemoprevention in children has remained limited. The proportion of children aged under 5 years with *Plasmodium falciparum* malaria who were treated with an ACT is estimated to have increased from less than 1% in 2005 to 16% in 2014 (WHO, 2015).

While this massive rollout of prevention and treatment tools has not yet reached intended coverage, it has resulted in sizeable progress in malaria control. Bhatt et al. (2015) find that since 2000, *Plasmodium falciparum* infection prevalence in endemic Africa halved, the incidence of clinical disease fell by 40% and approximately 663 million clinical cases have been averted. WHO estimates that since 2000, malaria mortality in the African Region rates have fallen by 66% among all age groups, and by 71% among children under five (WHO, 2015). While it is

widely recognized that the effects of malaria and antimalarial interventions extend far beyond the direct measures of fatalities and disease occurrence, estimates of such effects outside of trials remain limited.

1.2.2 Malaria in Pregnancy and Birth Outcomes

A large body of medical and epidemiological literature documents the devastating effect of malaria in pregnancy on the newborn infant, although most of the estimates come from small randomized controlled trials (Eisele et al., 2012). In areas of high malaria transmission in Africa, the risk of LBW (conventionally defined as birth weight <2500 g) is estimated to approximately double if women have placental malaria, with the greatest effect in first births (2–7 times higher than other birth orders) (Desai et al., 2007). In sub-Saharan Africa, nearly 20% of LBW deliveries are thought to be attributable to malaria in pregnancy, which represents 35% of preventable LBW in women of all pregnancy orders. Malaria-attributable LBW is estimated to be responsible for between 62,000 and 363,000 infant deaths every year in Africa, or 3 to 17 deaths per 1,000 live births. As many as 11.4% of neonatal deaths and 5.7% of all infant deaths in malaria-endemic areas of Africa may be caused by malaria-attributable LBW. This effect is greatest in first born infants at 17.6% of neonatal deaths and 9.8% of infant deaths.

Numerous randomized controlled trials conducted in sub-Saharan Africa and other endemic regions have shown that IPTp and ITN usage are associated with reduced risk of LBW (Desai et al. (2007) provide a review of relevant studies). Informed by this epidemiological evidence, the World Health Organization (WHO) has developed specific recommendations for controlling malaria and its effects during pregnancy in areas of stable transmission. The recommended package of interventions includes promotion and use of ITNs, administration of

IPTp-SP, and appropriate case management through prompt and effective treatment of malaria in pregnant women (WHO, 2014).

WHO recommends IPTp-SP in all areas with moderate to high malaria transmission in Africa, as part of antenatal care (ANC) services. Specifically, IPTp-SP is recommended for all pregnant women at each scheduled ANC visit starting as early as possible in the second trimester and until the time of delivery, provided that the doses are given at least one month apart (WHO, 2014). WHO recommends a schedule of four ANC visits (WHO, 2015). While SP is supposed to be made available at ANC clinics, so that pregnant women have immediate access to IPTp-SP during routine care, data reported by National Malaria Control Programs and nationally representative household surveys indicate stark differences between the proportion of women attending ANC clinics (91% (median) in 2014) and the proportion receiving the first and subsequent doses of IPTp (first dose: 64% (median), second dose: 45% (median), third dose: 21% (median)) in sub-Sahahran Africa. An estimated 15 million of the 28 million eligible pregnant women at risk did not receive a dose of IPTp (WHO, 2015). These differences verify missed opportunities to deliver IPTp during ANC visits. Similarly, while ITNs, which are recommended to be provided as early in pregnancy as possible and used throughout the entire pregnancy and the postpartum period, are distributed to pregnant women through ANC clinics using free distribution or a voucher system when available, the scale-up of ITNs has been uneven with sizeable gaps in coverage.

1.3 DATA CONSTRUCTION AND DESCRIPTIVE STATISTICS

1.3.1 Demographic and Health Surveys

The first data source for this study is the Demographic and Health Surveys (DHS), a data collection option within the DHS Program, a USAID-funded project implemented by ICF International. DHS are nationally representative household surveys that provide data on a broad range of monitoring and impact evaluation indicators within the scope of demography, health, and nutrition.[2]

For this analysis, I use individual- and household-level data on malaria preventive behaviors, fertility and socio-demographic characteristics from the Household and the Individual Woman's DHS Questionnaires. The Reproduction section of the DHS Woman's Questionnaire contains detailed birth histories for all children born to women in the sample, including dates of birth. Additionally, the Pregnancy and Postnatal Care section provides supplementary information on the births that occurred in the last 5 years prior to the survey, along with birth weight (for children weighed at birth, as recorded from a health card or from recall) and size at birth (for all children in the sample, as reported subjectively by the respondent), as well as information on any ANC received during the last pregnancy that resulted in a live birth, including use of antimalarial drugs. Given the scope of available information, this chapter concentrates on the respondent's last live birth within 5 years prior to the time of the survey.

The outcomes of interest are (i) whether the child weighed less than 2,500 g at birth, (ii) whether the child was smaller than average in size at birth as reported subjectively by the respondent, (iii) whether the child was very small in size at birth as reported subjectively by the respondent, and (iv) the child's birth weight in grams. In order to accurately estimate the impact of antimalarial interventions on LBW incidence, I use both the conventional definition of LBW

[2] DHS datasets are available free of charge for registered users at http://dhsprogram.com/data/available-datasets.cfm.

based on the child's weight at birth (< 2,500 g) as well as the subjectively reported categorical data on the size of the baby due to the fact that not all infants are weighed at birth. In the sample, only 51.6% of the babies were weighed at birth (143,131 out of 277,245).

The DHS Questionnaires also contain information on the mother's background, including level of education, as well as household characteristics, including type of residence (urban or rural), and household wealth quintile.[3]

I use a total of 42 surveys from 22 sub-Saharan countries. Table 1.1 summarizes data sources. Table 1.2 presents an overview of the DHS surveys used in the analysis.

1.3.2 Malaria Atlas Project

The second data source for this study is the Malaria Atlas Project (MAP), a non-profit collaboration hosted within the Division of Mathematical, Physical, and Life Sciences (MPLS) at the University of Oxford and funded by the Wellcome Trust, the Bill and Melinda Gates Foundation, the Global Fund, and a number of smaller foundations.[4]

MAP predicts the *Plasmodium falciparum* infection prevalence at different locations to provide estimates of malaria endemicity and presents these predictions in the form of maps. In particular, MAP relies on Bayesian model-based geostatistical approach to estimate the percentage of children between the ages of 2 and 10 with detectable levels of the *Plasmodium falciparum* parasite in the peripheral blood in a given region, or $PfPR_{2-10}$, since this measure is associated with a plateau in the age-prevalence relationship and thus acts as a standardized

[3] Using principal components analysis, DHS calculates a wealth index measure based on data on a household's ownership of selected assets, such as televisions and bicycles; materials used for household construction; and types of water access and sanitation facilities. The wealth index places individual households on a continuous scale of relative wealth and is a composite measure of a household's cumulative living standard. DHS then sorts all interviewed households into five wealth quintiles.

[4] MAP data is publicly available at www.map.ox.ac.uk.

comparison. $PfPR_{2-10}$ is estimated as a function of nearby malariometric survey data – which are weighted in each prediction according to their spatial and temporal proximity – and of a rich set of special environmental covariates, including climatology surfaces interpolated from networks of meteorological stations and remotely sensed data from Earth observation satellites.[5]

To identify populations at different levels of risk, I calculate average transmission intensity for each sub-country region and year using MAP data on PfPR. I obtain raster files from MAP containing predicted spatio-temporal cube of age-structured PfPR at 5×5 km resolution across all endemic African countries for each year from 2000 to 2015, overlay the regions boundaries, and calculate average values of $PfPR_{2-10}$ for each sub-country region in the sample. In particular, I am interested in identifying the starting (pre-intervention) malaria intensity in each region as measured by $PfPR_{2-10}$ in 2000.

Figure 1.1 demonstrates the variation in the initial (pre-intervention) $PfPR_{2-10}$ in 2000 across the 22 countries included in the analysis, as well as the evolution of $PfPR_{2-10}$ across time during the study period.

In addition to generating disease intensity estimates, MAP combines household-level data on ITN use and access to ACTs from various surveys with national malaria control program data on ITN, ACT and IRS provision to develop time-series models of coverage of these interventions within each country. ITN coverage data has similar structure to that of $PfPR_{2-10}$ and provides modelled values for usage of ITNs for the years 2000 – 2015 measured as the percentage of individuals who slept under an ITN on any given night for all African countries where *Plasmodium falciparum* malaria is endemic. IRS and ACT coverage are measured as the percentage of the population protected by IRS of insecticides and the percentage of cases of fever in under-5 year olds that were treated with ACT, respectively. Both IRS and ACT

[5] Gething et al. (2011) provide details on the construction of $PfPR_{2-10}$.

information is available for all years from 2000 to 2015 for all African countries where *Plasmodium falciparum* malaria is endemic, however there is only a single value for each country in each year.

MAP does not provide data on IPTp coverage, thus I use DHS Women's Questionnaires to identify infants whose mothers reported receiving at least one dose of IPT during their last pregnancy.

Figure 1.2 displays trends in IPTp-SP and ITN usage during the study period.[6] Figure 1.3 demonstrates the evolution of IRS and ACT coverage.[7]

1.3.3 Kiszewski et al., 2004

The third data source for this study is Kiszewski et al., 2004. The authors derive a spatial index of the stability of malaria transmission based on species-specific vector bionomics, vegetation, altitude, monthly precipitation thresholds, and monthly temperature thresholds to determine vectorial capacity[8]. The resulting index is presented in the form of maps with the 0.5-degree cell resolution[9] and examines potential transmission stability of malaria which is exogenous to public health interventions and economic conditions.

This chapter uses (sub-country) regional average values of the Kiszewski malaria stability index as an alternative measure of malaria intensity in addition to $PfPR_{2-10}$ in 2000.

[6] Figures B1 and B2 in Appendix B show variation in region-level IPTp coverage and ITN use across countries in Sub-Saharan Africa in 2000–2013, respectively.

[7] Figures B3 and B4 in Appendix B show variation in country-level IRS and ACT coverage in Sub-Saharan Africa in 2000–2013, respectively.

[8] Vectorial capacity is generally defined as the rate (usually daily) at which a bloodsucking insect population generates new inoculations from a currently infectious case. It is the most important characteristic of vector species from the epidemiological perspective. Vectorial capacity is a measure of potential, rather than actual, rate of transmission, as it contains no parasitological information.

[9] 0.5-degree cells resolution is approximately equivalent to 50 km grid.

While the Kiszewski malaria stability index is not a measure of disease intensity but rather of malaria suitability, in the absence of antimalarial interventions prior to 2000, this index is a plausibly strong proxy for malaria prevalence in the year 2000.

1.3.4 Sample Restriction and Descriptive Statistics

I consider all countries for which both DHS (standard and continuous) survey data and MAP $PfPR_{2-10}$ files are available and restrict the sample to the live births which occurred from 2000 to 2013. The effective sample data comprises 255 regions in 22 countries. Using region of residence of the household as the panel variable and year of birth as the time variable, I create a panel for the analysis conducted in this chapter. For some countries, the boundaries of some regions have changed between surveys conducted in different years. In these instances, I combine regions using maps provided in the public report of each survey to ensure consistency over time.

Descriptive statistics are reported in Table 1.4. Column (1) describes all children in the dataset. The full sample includes both children weighed at birth and those who were not. For each of these children, I have data on their size at birth as reported subjectively by the respondent. 15.8% of children are reported to be smaller than average at birth, and 4.8% are reported to be of very small size at birth. Column (2) describes the subsample of children weighed at birth. For each of these children, I have information on their birth weight in grams. Average birth weight in this subsample is 3,227 grams, 9.2% of the children are of LBW (< 2,500 g). Column (3) summarizes data on the children not weighed at birth. Comparison of columns (2) and (3) shows that children weighed at birth are different from those who were not in many ways. Children weighed at birth are more likely to be born in urban areas (43.3% vs.

15.9%), wealthier households (3.3 vs. 2.4 average wealth quintile), and to educated mothers (35.8% vs. 22.8% for primary education and 33.5% vs. 10.9% for at least secondary education) and mothers who were more likely to follow the ANC recommendations (63.6% vs. 38.2% reported four or more ANC visits).

The observational unit for this analysis is a live birth. In the analysis, I use both the subsample of children weighed at birth as well as the full sample of all children, as the former may not be representative of the general population. The total number of observations used is 277,245 including 143,131 children weighed at birth.

1.4 RESEARCH STRATEGY

The goal of this chapter is to assess the effects of malaria control measures on birth outcomes by performing a reduced form linear estimation of a health production function in which antimalarial interventions are the inputs of primary interest. A simple model is presented in the Appendix A. The key idea of the model is that malaria preventive behaviors in pregnancy affect maternal health, which in turn affects infant health, however the sign of this indirect effect of malaria prevention on infant health status is ambiguous. While those pregnancies which would have ended in a live birth with or without malaria prevention, would have benefitted from the interventions and resulted in healthier children, the pregnancies that would have ended in a miscarriage in the absence of antimalarial interventions, may now have resulted in a live birth, albeit the child health status may have been poor. Thus, estimating the parameters of the health production function is necessary for predicting and assessing effects of public policies. To do this, I exploit the geographic and time variation in the rollout of antimalarial interventions in sub-Saharan Africa across regions with different levels of initial malaria prevalence in a continuous

difference-in-differences estimation framework. The key intuition behind the empirical strategy is that benefits of antimalarial interventions likely differ across regions with different starting (pre-intervention) malaria endemicity as well as with the degree of malaria control coverage.

The first source of variation in the data comes from the pre-intervention malaria endemicity, measured by $PfPR_{2-10}$ in 2000, which ranges from 0.006 to 0.882, and the Kiszewski malaria stability index, which ranges from 0.000 to 34.314. Recent research documents that the individual as well as combined efficacy of interventions varies by setting and is contingent on many local factors, including vector ecology, health systems, and coverage levels (Bhatt et al., 2015; Lim et al., 2011; Lengeler, 2004), as well as the extent of spatial externalities to intervention coverage (Gimnig et al., 2003). Thus, if effectiveness of IPTp, ITNs, IRS, and ACT in preventing malaria infections varies across regions with different transmission risk, it is plausible that improvements in birth outcomes will also vary with pre-intervention disease intensity. In this case, the non-malarious areas serve as a comparison group, filtering out common trends.

The second source of variation in the data comes from the degree of the intervention coverage across different countries and sub-country regions. Prior to the introduction of MDGs in 2000, malaria control measures were extremely limited, and even after the start of antimalarial campaigns the depth of the distribution of IPTp and ITNs was not uniform across countries. For example, MAP estimates that, in 2012, only 15% of individuals in Nigeria slept under an ITN on any given night, whereas in Ghana, in same year over 44% of population slept under an ITN. I am most interested in the effects of the malaria control measures recommended to pregnant women: ITN use and IPTp. I additionally control for IRS and ACT usage at the country-year level.

To implement this empirical strategy, I follow an econometric approach most similar to that of as Apouey et al. (2017) and Wilde et al. (2017) in their analysis of anemia and mortality and fertility in sub-Saharan Africa, respectively.[10] Specifically, for a child *i* who was born in country *c*, region *r*, month *m*, and year *t*, I estimate the following equation:

$$\begin{aligned} B_{icrmt} = \alpha + \beta_1 IPTpSP_{icrmt} + \beta_2 IPTpSP_{icrmt} \times \left(Mal_r - \overline{Mal}\right) + \beta_3 ITN_{rt} \\ + \beta_4 ITN_{rt} \times \left(Mal_r - \overline{Mal}\right) + \beta_5 IRS_{ct} + \beta_6 IRS_{ct} \times \left(Mal_r - \overline{Mal}\right) \\ + \beta_7 ACT_{ct} + \beta_8 ACT_{ct} \times \left(Mal_r - \overline{Mal}\right) + \Pi X_{icrmt} + \gamma_t + \delta_r + \theta_{cm} \\ + \lambda_{ct} + \delta_r \times trend + \epsilon_{icrmt}, \end{aligned} \quad (1)$$

where B_{icrmt} is the birth outcome (either a LBW indicator variable (1 if the child is of LBW, 0 otherwise) or birth weight in grams), Mal_r is the pre-intervention malaria endemicity, $\overline{Mal}$ is the average level of Mal_r for all regions, $IPTpSP_{icrmt}$ is an indicator for whether the mother of the child received IPT during the pregnancy, ITN_{rt}, IRS_{ct}, ACT_{ct} are the ITN usage, IRS and ACT coverage during pregnancy, respectively, and X_{icrmt} is a vector of individual controls: type of residence dummy (1 if urban, 0 if rural), household wealth quintile, maternal education variables (indicate whether the mother has primary or at least secondary education as compared to no education group), ANC utilization variables (indicate whether the mother visited an ANC facility at most 3 times or at least 4 times as compared to no ANC during pregnancy), mother's age at birth, gender of the child (1 if male, 0 if female), firstborn indicator variable, birth spacing variable (1 if the preceding birth interval is under 24 months, 0 otherwise). Finally, γ_t is a year fixed effect (to control for trends in outcomes across years in all countries), δ_r is a region fixed effect (to control for permanent differences in outcomes across regions), θ_{cm} is a country-month

[10] This approach is also similar in spirit to that used by Bleakley (2007, 2010), Fortson (2009, 2011), Lucas (2010, 2013) and many others.

fixed effect (to control for seasonality of both malaria transmission risk and birth outcomes), λ_{ct} is a cohort (country-year) fixed effect (to control for country-specific trends in outcomes), $\delta_r \times trend$ is an interaction term between region-specific indicators and a yearly linear time trend (to control for differences in linear trends in outcomes across sub-country regions and relax the identification assumption of parallel trends between treatment and control groups) and ϵ_{irt} is the disturbance.

I estimate equation (1) using ordinary least squares[11] and cluster the standard errors at the region level to allow for arbitrary correlation among observations in the same region over time. I am most interested in estimating the effects of IPTp and ITN coverage on birth outcomes. Because I demean Mal_r, I interpret the coefficients β_1 and β_3 as the average partial effect of IPTp-SP and ITN evaluated at the mean value of malaria prevalence instead of zero. Additionally, I am interested in the coefficients β_2 and β_4, since they measure the additional effects of IPTp-SP and ITNs in regions with levels of malaria endemicity that are different from $\overline{Mal}$. These coefficients can be interpreted as difference-in-differences estimators since even though all regions received antimalarial interventions and should have experienced improvements in birth weight outcomes, such improvements may have been different for regions with higher or lower malaria endemicity relative to those regions with close to the average level of malaria endemicity.

For this empirical approach to be valid and able to identify the true effect of IPTp and ITN use during pregnancy on birth outcomes, the exposure to antimalarial interventions must be exogenous. If IPTp use is an individual or household-level decision, a potential concern is that

[11] For ease of interpretation and to maintain consistency across specifications with continuous and binary dependent variables, all estimations are conducted using ordinary least squares. The results are not sensitive to changes in specification or alternative estimation procedures. Tables B1–B4 in Appendix B present results from alternative specifications. APE results obtained from probit models estimation (not reported) are also very similar.

mothers who receive IPTp doses during pregnancy are not comparable to mothers who do not receive IPTp doses during pregnancy, and therefore the potential birth outcomes of their children are likely quite different. If, for example, mothers who are less likely to have LBW children within a given region are also more likely to take-up preventative health treatments (like IPTp) when they become available in that region, then even with inclusion of cohort fixed effects and region fixed effects, the true causal effect of IPTp use will be confounded with the selection of "better" mothers into the take-up of IPTp. I try to alleviate these concerns by focusing on measures of access to the malaria control treatments, not the individual decisions to take IPTp or use ITNs. The ITN variable is the percentage of individuals who slept under an ITN on any given night during the 9 months prior to a given birth which I interpret as the likelihood that a given mother had access to a bed net during her pregnancy.[12] The IPTp variable is an indicator for whether the mother of the child received IPT during the pregnancy at least once. According to published WHO reports, it is unusual that a woman declines IPTp at an ANC facility if it is available. Thiam et al. (2012) provide an overview of the evidence on the barriers for IPTp coverage in sub-Saharan Africa and conclude that individual level factors strongly associated with the use of IPTp are limited and adherence levels are high among women offered IPTp. I control for ANC attendance, which is highly correlated with receipt of IPTp, in order to disentangle the distinct effects of IPTp from those of ANC attendance, as the latter could plausibly reduce the incidence of LBW in other ways.

The estimates identify the effects of antimalarial efforts even though malaria control officials may have targeted regions based on the pre-rollout level of malaria endemicity and poor

[12] Under perfect circumstances, a better measure of access to ITNs would have been the percentage of individuals or households who received a net within a particular time period. While DHS surveys contain information on both bed net usage and ownership, these data are only available as of the time of the survey. Since this analysis focuses on the respondent's last live birth within 5 years prior to the time of the survey, variables available through DHS are poor proxies of bed net usage or ownership at the time of the pregnancy. Malaria Atlas Project does not collect nor disseminate data on bed net provision or ownership.

birth outcomes in these regions because I control for both region fixed effects and the pre-rollout level of malaria endemicity. The key assumption in the identification strategy is that in the absence of the antimalarial interventions there were no changes in birth weight concurrent to the interventions and correlated with the malaria endemicity. This would be the case if, for example, infant birth weight was increasing the fastest in areas where malaria endemicity was the highest when there were no antimalarial campaigns. I conduct falsification checks (presented in Section 5.2) to ensure that this unlikely scenario is not affecting the estimates.

1.5 RESULTS

1.5.1 Main Results

The main results of the analysis are presented in Table 1.5. Informed by the epidemiological evidence of greater effectiveness of antimalarial interventions for first births (discussed in greater detail in sub-section 1.2.2), I conduct a subsample analysis for firstborn children only (columns (1) through (4)), in addition to estimating the effects for the full sample of children of all birth orders (columns (5) through (8)). In both samples, I use the subjectively reported measures of LBW for all children, as well as the conventional, objective measure of LBW based on birth weight in grams for children weighed at birth.

In Table 1.5, the dependent variables are (i) whether the child was LBW (< 2,500 g) (columns (1) and (5)), (ii) whether the child was smaller than average in size at birth as reported subjectively by the respondent (columns (2) and (6)), (iii) whether the child was very small at birth as reported subjectively by the respondent (columns (3) and (7)), and (iv) birth weight in grams (columns (4) and (8)). In all specifications, I include a variety of socio-demographic

controls as explanatory variables, as well as control for cohort (country-year), country-month, and region fixed effects.

In Table 1.5, the coefficients for IPTp-SP are always negative and statistically significant for all measures of LBW (columns (1) through (3) and (5) through (7)) with larger effects for firstborn children. In areas with average levels of malaria, firstborn infants of mother with access to IPTp-SP were 1.2 percentage points less likely to be LBW, 1.5 percentage points less likely to be small and 1.4 percentage points less likely to be very small (vs. 12.5%, 18.5% and 5.8% average, respectively). Thus, in areas with average initial malaria endemicity, access to IPTp-SP reduced the likelihood of LBW by 9.5%, of small births by 8.1%, and of very small births by 24.1% for first births, all else equal. Children of all birth orders in areas with average initial malaria endemicity born to mothers who had access to IPTp-SP were on average 1.0 percentage point less likely to be LBW and 1.3 percentage points less likely to be small or very small (vs. 9.2%, 15.8%, 4.8% average, respectively). Thus, in areas with average initial malaria endemicity, access to IPTp-SP reduced the likelihood of LBW by 10.9%, of small births by 8.2%, of very small births by 27.1% for all birth orders, all else equal. These effects, while large in magnitude, are significantly more modest than those reported in epidemiological studies.[13] This is not surprising given that the goal of the present analysis is to estimate the average effect of provision of access to antimalarial interventions under routine conditions and not in a trial setting.[14]

[13] McClure et al. (2013) provide an overview of published studies. For example, Desai et al. (2007) report that malaria prevention in pregnancy through IPTp-SP and ITNs significantly reduces the prevalence of LBW by as much as 43%.

[14] For example, Le Port et al. (2011) evaluated the efficiency of malaria prevention in pregnancy in a clinical trial setting in Benin, as well as subsequently, when the Benin government scaled-up the IPTp-SP program, and the results of the national scale-up were significantly more modest than in trials.

On the other hand, the effect of ITN usage at the average malaria endemicity has no clear pattern and is not statistically significant. A potential explanation is that I cannot measure whether a particular mother slept under an ITN during her pregnancy. I approximate this variable with the percentage of individuals in a given region during the 9 months preceding a given birth who reported sleeping under an ITN the night before the interview which may be a poor proxy for ITN availability.

Finally, the socio-demographic controls have the expected signs and are usually statistically significant.[15] For example, household wealth, mother's education, male gender of the child, and receipt of ANC reduce the probability of LBW and of small or very small size of child at birth; while preceding birth interval of less than 24 months and first birth order increase the probability of poor birth outcomes.

1.5.2 Robustness and Falsification Checks

I re-estimate the main specification using an alternative measure of pre-intervention malaria intensity, Kiszewski malaria stability index. The results are presented in Table 1.6.

The estimated effects of antimalarial interventions on birth outcomes are robust to the inclusion of the alternative malaria endemicity measure. Coefficients for IPTp-SP remain negative and statistically significant for all measures of LBW (columns (1) through (3) and (5) through (7)) and are nearly identical in magnitude to those obtained in the previous subsection. Notably, in columns (1) and (5) (dependent variable – indicator for whether the child weighed less than 2,500 g at birth) the coefficient on the interaction term of IPTp-SP and Kiszewski index is negative and statistically significant at the 5% level for all children and 1% level for firstborn

[15] Table 1.5 reports the estimated coefficients for the main variables of interest only and thus omits the coefficients on the socio-demographic controls, which are instead shown in Tables B1–B4 in Appendix B.

children, suggesting that areas with higher levels of pre-intervention malaria endemicity had more to gain from malaria control. For the other outcomes of interest, the interaction terms of IPTp-SP and Kiszewski index are imprecisely estimated zeros, and the main coefficients on IPTp-SP are very similar to those obtained in the main results.

I then conduct a series of specification checks to ensure that the results presented thus far are due to malaria control measures and not driven by other factors occurring at the same time as the antimalarial interventions. Given the main specification, any confounding effects would have to vary at the region-year level, as well as correlate with the level of malaria. For instance, it would be problematic if regions that would have experienced more rapid improvement in birth outcomes over the 2000s in the absence of any change in antimalarial behaviors were also more likely to receive and use IPTp-SP, ITNs, IRS, and ACT. This might have occurred if, for example, some regions were simply more likely to receive assistance to help them achieve any of the MDGs. In this case the regions where there was a larger increase in, for example, ITN availability (MDG 6) would also be the regions where more aid was targeted for decreasing early childhood mortality (MDG 4).

First, I ask whether any nutritional changes concurrent with the availability of malaria preventive treatments and correlated with pre-intervention malaria endemicity may have contributed to the changes in birth outcomes estimated in Table 1.5. Since maternal caloric intake and nutritional stores are the sole source of fetal energy requirements, pre-pregnancy weight, gestational nutrition, and weight gain are important determinants of birth weight (Kramer, 1987). Select DHS surveys contain information on nutrition of mothers of children under 36 months. Specifically, the questionnaires ask whether the mother consumed particular foods and beverages in the day and night prior to survey. I re-run the main specification (1) using

the following indicators as dependent variables: whether the mother had any meat (such as beef, pork, lamb, goat, chicken, or duck), eggs, or potatoes. These foods are nutritionally rich and their consumption is highly correlated with caloric intake. Additionally, I re-estimate the main specification using mother's body mass index (BMI) as a dependent variable. The results are reported in columns (1) – (4) of Table 1.7. I find that the availability of IPTp-SP, ITNs, IRS, and ACT did not have any statistically significant impact on maternal nutrition or BMI, thus I find no evidence of nutrition-related factors confounding the estimates.

Second, I test whether the effects of antimalarial interventions on birth weight estimated in Table 1.5 may have been generated by other general welfare factors. I re-run the main specification using wealth and asset ownership indicators (dummies for electricity in household and ownership of a television) as dependent variables. The results are reported in columns (5) and (6) of Table 1.7. The effects of antimalarial interventions on the likelihood of living in an electrified household or owning a television are not statistically significant, which lends further credibility to the main analysis.

1.5.3 Mortality Selection Effects

The estimates of the effect of IPTp and ITN distribution on birth outcomes may be influenced by mortality selection effects. WHO estimates that even with a large growth in underlying population, the number of malaria deaths in children under 5 in the WHO African Region fell from 694,000 in 2000 to 292,000 in 2015 (WHO, 2015). If antimalarial interventions affected not only child mortality but also *in utero* mortality, this would lead to estimates that are smaller (less negative) than the true relationship and make the benefits of malaria prevention measures appear less pronounced.

For instance, in Table 1.5, the coefficients on the interaction terms of IPTp-SP and malaria prevalence are positive and statistically significant both for firstborns as well as for children of all birth orders for the very small size at birth outcome (columns (3) and (7)). It is plausible that the marginal fetuses who were more likely to die *in utero* in the absence of interventions in highly endemic areas, are now more likely to survive and be very small at birth due to availability of IPTp-SP. Furthermore, the coefficients on IPTp-SP for the birth weight outcome (columns (4) and (8)) are negative, although not statistically significant, while the coefficients on the interactions of IPTp-SP and malaria prevalence for the same outcomes are negative, significant, and large in magnitude. This suggests that antimalarial interventions may have affected the distribution of survivors.

Ideally I would like to investigate whether regions with increasing IPTp/ITN use over the study period also saw decreases in *in utero* mortality. While DHS surveys contain some information on non-live births and miscarriages, I cannot distinguish such incidents from induced abortions in the data, as the DHS question asks "Have you ever had a pregnancy that miscarried, was aborted, or ended in a stillbirth?" Instead, to provide suggestive evidence on the magnitude of mortality selection, I estimate the effects separately for firstborn boys and firstborn girls.

First pregnancies are associated with worse pregnancy outcomes, including greater likelihood of LBW and lower average birth weight, and are thus most likely to be affected by possible mortality effects (Kramer, 1987). Furthermore, while both male and female fetuses are negatively affected by malaria, the literature on "fragile males" has found male fetuses to be more vulnerable to detrimental conditions *in utero* than female fetuses (e.g. Kraemer, 2000; Eriksson et al., 2010; Almond and Mazumder, 2011; Currie and Schwandt, 2016; Dinkelman,

2017). While the heterogeneity of the effects of fetal shocks across genders can potentially also be explained by gender preference, I do not expect this to impact the results, as in sub-Saharan Africa behaviors reveal preference for variety or no preference (Rossi and Rouanet, 2015). Firstborn boys are, thus, likely to be affected the most by mortality selection, and evaluating the effects of antimalarial interventions using this subsample would yield the most conservative (lower bound) estimates. Similarly, non-firstborn girls are least likely to be affected by mortality selection and, therefore, the estimation of antimalarial interventions on this subsample would yield the upper bound for the estimates.

The effects, estimated separately for firstborn boys and non-firstborn girls, are presented in Table 1.8.

The estimates in Table 1.8 suggest that the effects of IPTp-SP for firstborn boys are slightly smaller in magnitude for measures of LBW (columns (1) through (3) and (5) through (7)) as well as for for birth weight in grams (columns (4) and (8)) (more negative, although not statistically significant) than those for non-firstborn girls. This is consistent with the "fragile males" hypothesis: if male fetuses are more vulnerable to the negative effects of malaria, availability of IPTp-SP increases their survival chances, while at the same time making the marginal survivor be born LBW. Thus, the overall effect of reduction in LBW incidence is smaller for boys than it is for girls. At the same time, the magnitude of the difference in coefficients across the two subsamples is very small, which suggests that the main analysis is not likely to be significantly impacted by mortality selection effects and thus provides accurate estimates of the average partial effects of antimalarial interventions.

1.6 DISCUSSION AND CONCLUSION

Malaria control is one of the highest priorities on the international development agenda which is currently defined around two key policy initiatives for the 2016–2030 period: the Global Technical Strategy and Action and Investment to Defeat Malaria, led by WHO and the Roll Back Malaria Partnership. The primary goals comprise universal access to malaria prevention, diagnosis, and treatment, accelerated efforts towards elimination of malaria and attainment of malaria-free status, as well as transforming malaria surveillance into a core intervention. Estimates suggest that annual investments in malaria control and elimination will need to increase to US$ 6.4 billion per year by 2020, US$ 7.7 billion by 2025 and US$ 8.7 billion by 2030 to meet these objectives (Bhatt et al., 2015).

The effectiveness of insecticide-based vector control is threatened by malaria mosquitoes developing resistance to the insecticides used in ITNs and IRS. Similarly, antimalarial drug resistance has also been reported in various endemic countries. Despite the observed changes in parasite sensitivity, which manifest in the form of delayed parasite clearance, patients continue to respond to treatment, and long-lasting insecticidal nets remain effective (WHO, 2015). Analysis of progress provides means to monitor the success of international control efforts in achieving their goals and targets. Achievements of malaria interventions should be robustly evaluated to inform optimal policy strategy for the future.

The present study aims to complement the existing literature on the effectiveness of specific malaria control measures by estimating the effect of provision of access to interventions (as opposed to adherence to recommendations with respect to treatments) in a real-world setting. I estimate that the availability of IPTp-SP has contributed to improvements in birth outcomes in sub-Saharan Africa and decreased the likelihood of LBW by 10.9% in areas with average initial

malaria prevalence, all else equal. The estimates provided in this chapter are much smaller in magnitude that those reported in numerous trials which find that malaria prevention in pregnancy through IPTp-SP and ITNs under the conditions of perfect provision and monitored compliance significantly reduces the prevalence of LBW by as much as 43% (Desai et al., 2007). These findings highlight the missed opportunities to deliver treatment and ensure proper adherence of those in need.

This analysis is not without limitations. This study uses a reduced form approach rather than a structural model. The effects of antimalarial interventions on birth outcomes obtained in this chapter should be interpreted as intent-to-treat (ITT) estimates rather than the average treatment effect on the treated (ATET). Any geographic spillover effects of malaria control measures on neighboring regions are not captured in this analysis. This chapter does not consider potential longer-run child health outcomes which may plausibly be impacted by antimalarial interventions.

1.7 REFERENCES

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

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

Almond, D., & Currie, J. (2011b). Killing me softly: The fetal origins hypothesis. *The Journal of Economic Perspectives: A Journal of the American Economic Association*, *25*(3), 153.

Almond, D., Edlund, L., Li, H., & Zhang, J. (2010). Long-term effects of early-life development: Evidence from the 1959 to 1961 China famine. In T. Ito & A. Rose (Eds.), *The economic consequences of demographic change in East Asia, NBER-EASE Volume 19* (pp. 321-345). University of Chicago Press.

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

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

Apouey, B. H., Picone, G., Wilde, J., Coleman, J., & Kibler, R. (2017). Paludisme et anémie des enfants en Afrique subsaharienne: Effet de la distribution de moustiquaires. *Revue économique, 68*(2), 163-197.

Banerjee, A., Duflo, E., Postel-Vinay, G., & Watts, T. (2010). Long-run health impacts of income shocks: Wine and phylloxera in nineteenth-century France. *The Review of Economics and Statistics, 92*(4), 714-728.

Barreca, A. I. (2010). The long-term economic impact of in utero and postnatal exposure to malaria. *Journal of Human Resources*, *45*(4), 865-892.

Bhalotra, S. R., & Venkataramani, A. (2015). Shadows of the Captain of the Men of Death: Early life health interventions, human capital investments, and institutions. *Working paper.* Available at SSRN: http://ssrn.com/abstract=1940725 or http://dx.doi.org/10.2139/ssrn.1940725.

Bhatt, S., Weiss, D. J., Cameron, E., Bisanzio, D., Mappin, B., Dalrymple, U., ... & Wenger, E. A. (2015). The effect of malaria control on *Plasmodium falciparum* in Africa between 2000 and 2015. *Nature*, *526*(7572), 207-211.

Black, S.E., Bütikofer, A., Devereux, P., & Salvanes, K. (2014). This is only a test? Long-run and intergenerational impacts of prenatal exposure to radioactive fallout. *NBER Working Paper No. 18987*.

Bleakley, H. (2007). Disease and development: Evidence from hookworm eradication in the American South. *The Quarterly Journal of Economics*, *122*(1), 73-117.

Bleakley, H. (2010). Malaria eradication in the Americas: A retrospective analysis of childhood exposure. *American Economic Journal: Applied Economics*, *2*(2), 1-45.

Camacho, A. (2008). Stress and birth weight: Evidence from terrorist attacks. *The American Economic Review*, *98*(2), 511-515.

Chen, Y., & Zhou, L. A. (2007). The long-term health and economic consequences of the 1959–1961 famine in China. *Journal of Health Economics*, 26(4), 659-681.

Currie, J. (2011). Inequality at Birth: Some Causes and Consequences. *The American Economic Review*, *101*(3), 1-22.

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

Currie, J., & Rossin-Slater, M. (2015). Early-life origins of life-cycle well-being: Research and policy implications. *Journal of Policy Analysis and Management*, *34*(1), 208-242.

Currie, J., & Schwandt, H. (2016). The 9/11 Dust Cloud and Pregnancy Outcomes: A Reconsideration. *Journal of Human Resources, 51*(4), 805-831.

Currie, J., & Vogl, T. (2013). Early-life health and adult circumstance in developing countries. *Annual Revue of Economics*, *5*(1), 1-36.

Cutler, D., Fung, W., Kremer, M., Singhal, M., & Vogl, T. (2010). Early-life malaria exposure and adult outcomes: Evidence from malaria eradication in India. *American Economic Journal: Applied Economics, 2*(2), 72-94.

Desai, M., ter Kuile, F. O., Nosten, F., McGready, R., Asamoa, K., Brabin, B., & Newman, R. D. (2007). Epidemiology and burden of malaria in pregnancy. *The Lancet Infectious Diseases*, *7*(2), 93-104.

Dinkelman, T. (2017). Long-run health repercussions of drought shocks: Evidence from South African homelands. *The Economic Journal.* doi:10.1111/ecoj.12361

Eisele, T. P., Larsen, D. A., Anglewicz, P. A., Keating, J., Yukich, J., Bennett, A., ... & Steketee, R. W. (2012). Malaria prevention in pregnancy, birthweight, and neonatal mortality: A meta-analysis of 32 national cross-sectional datasets in Africa. *The Lancet Infectious Diseases*, *12*(12), 942-949.

Eriksson, J. G., Kajantie, E., Osmond, C., Thornburg, K., & Barker, D. J. (2010). Boys live dangerously in the womb. *American Journal of Human Biology*, *22*(3), 330-335.

Fortson, J. G. (2009). HIV/AIDS and Fertility. *American Economic Journal: Applied Economics*, 1(3), 170-194.

Fortson, J. G. (2011). Mortality risk and human capital investment: The Impact of HIV/AIDS in Sub-Saharan Africa. *The Review of Economics and Statistics*, 93(1), 1-15.

Gething P.W., Patil A.P., Smith D.L., Guerra C.A., Elyazar I.R., Johnston G.L., Tatem A.J., & Hay S.I. (2011). A new world malaria map: *Plasmodium falciparum* endemicity in 2010. *Malaria Journal*, *10*(1), 378.

Gimnig, J. E., Kolczak, M. S., Hightower, A. W., Vulule, J. M., Schoute, E., Kamau, L., ... & Hawley, W. A. (2003). Effect of permethrin-treated bed nets on the spatial distribution of malaria vectors in western Kenya. *The American Journal of Tropical Medicine and Hygiene*, *68*(4 suppl), 115-120.

Guyatt, H. L., & Snow, R. W. (2004). Impact of malaria during pregnancy on low birth weight in sub-Saharan Africa. *Clinical Microbiology Reviews, 17*(4), 760-769.

Kelly, E. (2011). The scourge of Asian flu in utero exposure to pandemic influenza and the development of a cohort of British children. *Journal of Human Resources*, *46*(4), 669-694.

Kramer, M. S. (1987). Determinants of low birth weight: Methodological assessment and meta-analysis. *Bulletin of the World Health Organization*, 65(5), 663-737.

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

Lauderdale, D. S. (2006). Birth outcomes for Arabic-named women in California before and after September 11. *Demography*, *43*(1), 185-201.

Lien, D. S., & Evans, W. N. (2005). Estimating the impact of large cigarette tax hikes the case of maternal smoking and infant birth weight. *Journal of Human Resources*, *40*(2), 373-392.

Evans, W. N., & Lien, D. S. (2005). The benefits of prenatal care: Evidence from the PAT bus strike. *Journal of Econometrics*, *125*(1), 207-239.

Kayentao, K., Garner, P., van Eijk, A. M., Naidoo, I., Roper, C., Mulokozi, A., ... & ter Kuile, F. O. (2013). Intermittent preventive therapy for malaria during pregnancy using 2 vs 3 or more doses of sulfadoxine-pyrimethamine and risk of low birth weight in Africa: Aystematic review and meta-analysis. *JAMA, 309*(6), 594-604.

Kiszewski, A., Mellinger, A., Spielman, A., Malaney, P., Sachs, S. E., & Sachs, J. (2004). A global index representing the stability of malaria transmission. *The American Journal of Tropical Medicine and Hygiene*, *70*(5), 486-498.

Kuecken, M., Thuilliez, J., & Valfort, M. A. (2015). Large-scale health interventions and education: Evidence from Roll Back Malaria in Africa. *Working paper.* Available at: ftp://mse.univ-paris1.fr/pub/mse/CES2013/13075R.pdf.

Lengeler, C. (2004). Insecticide-treated bed nets and curtains for preventing malaria. *Cochrane Database of Systematic Reviews (CDSR)*, 2(2).

Le Port, A., Cottrell, G., Dechavanne, C., Briand, V., Bouraima, A., Guerra, J., ... & Garcia, A. (2011). Prevention of malaria during pregnancy: Assessing the effect of the distribution of IPTp through the national policy in Benin. *The American Journal of Tropical Medicine and Hygiene*, *84*(2), 270-275.

Lindeboom, M., Portrait, F., & Van den Berg, G. J. (2010). Long-run effects on longevity of a nutritional shock early in life: The Dutch Potato famine of 1846–1847. *Journal of Health Economics*, *29*(5), 617-629.

Lucas, A. M. (2010). Malaria eradication and educational attainment: Evidence from Paraguay and Sri Lanka. *American Economic Journal: Applied Economics*, *2*(2), 46-71.

Lucas, A. M. (2013). The impact of malaria eradication on fertility. *Economic Development and Cultural Change*, 61(3), 607-631.

Lucas, A. M., & Wilson, N. L. (2013). Adult antiretroviral therapy and child health: Evidence from scale-up in Zambia. *The American Economic Review*, *103*(3), 456-461.

Mansour, H., & Rees, D. I. (2012). Armed conflict and birth weight: Evidence from the al-Aqsa Intifada. *Journal of Development Economics*, 99(1), 190-199.

McClure, E. M., Goldenberg, R. L., Dent, A. E., & Meshnick, S. R. (2013). A systematic review of the impact of malaria prevention in pregnancy on low birth weight and maternal anemia. *International Journal of Gynecology & Obstetrics*, *121*(2), 103-109.

Miguel, E., & Kremer, M. (2004). Worms: Identifying impacts on education and health in the presence of treatment externalities. *Econometrica*, *72*(1), 159-217.

Pell, C., Straus, L., Andrew, E. V., Meñaca, A., & Pool, R. (2011). Social and cultural factors affecting uptake of interventions for malaria in pregnancy in Africa: A systematic review of the qualitative research. *PLOS ONE*, *6*(7), e22452.

Rossi, P., & Rouanet, L. (2015). Gender preferences in Africa: A comparative analysis of fertility choices. *World Development*, 72, 326-345.

Simeonova, E. (2011). Out of sight, out of mind? The impact of natural disasters on pregnancy outcomes. *CESifo Economic Studies, 57*(3): 403-431.

Thiam, S., Kimotho, V., & Gatonga, P. (2012). Why are IPTp coverage targets so elusive in sub-Saharan Africa? A systematic review of health system barriers. *Malaria Journal*, *12*, 353-353.

Torche, F. (2011). The effect of maternal stress on birth outcomes: Exploiting a natural experiment. *Demography*, 48(4), 1473-1491.

Venkataramani, A. S. (2012). Early life exposure to malaria and cognition in adulthood: Evidence from Mexico. *Journal of Health Economics*, *31*(5), 767-780.

Wilde, J., Apouey, B. H., Coleman, J., & Picone, G. (2017). The effect of antimalarial campaigns on child mortality and fertility in sub-Saharan Africa. *Working paper.* Available at: http://economics.usf.edu/PDF/Mort_Fert_Malaria.pdf.

World Health Organization (2014). WHO policy brief for the implementation of intermittent preventive treatment of malaria in pregnancy using sulfadoxine-pyrimethamine (IPTp-

SP). Available at: http://www.who.int/malaria/publications/atoz/iptp-sp-updated-policy-brief-24jan2014.pdf?ua=1.

World Health Organization (2015). World Malaria Report 2015. Available at: http://www.who.int/malaria/publications/world-malaria-report-2015/report/en/.

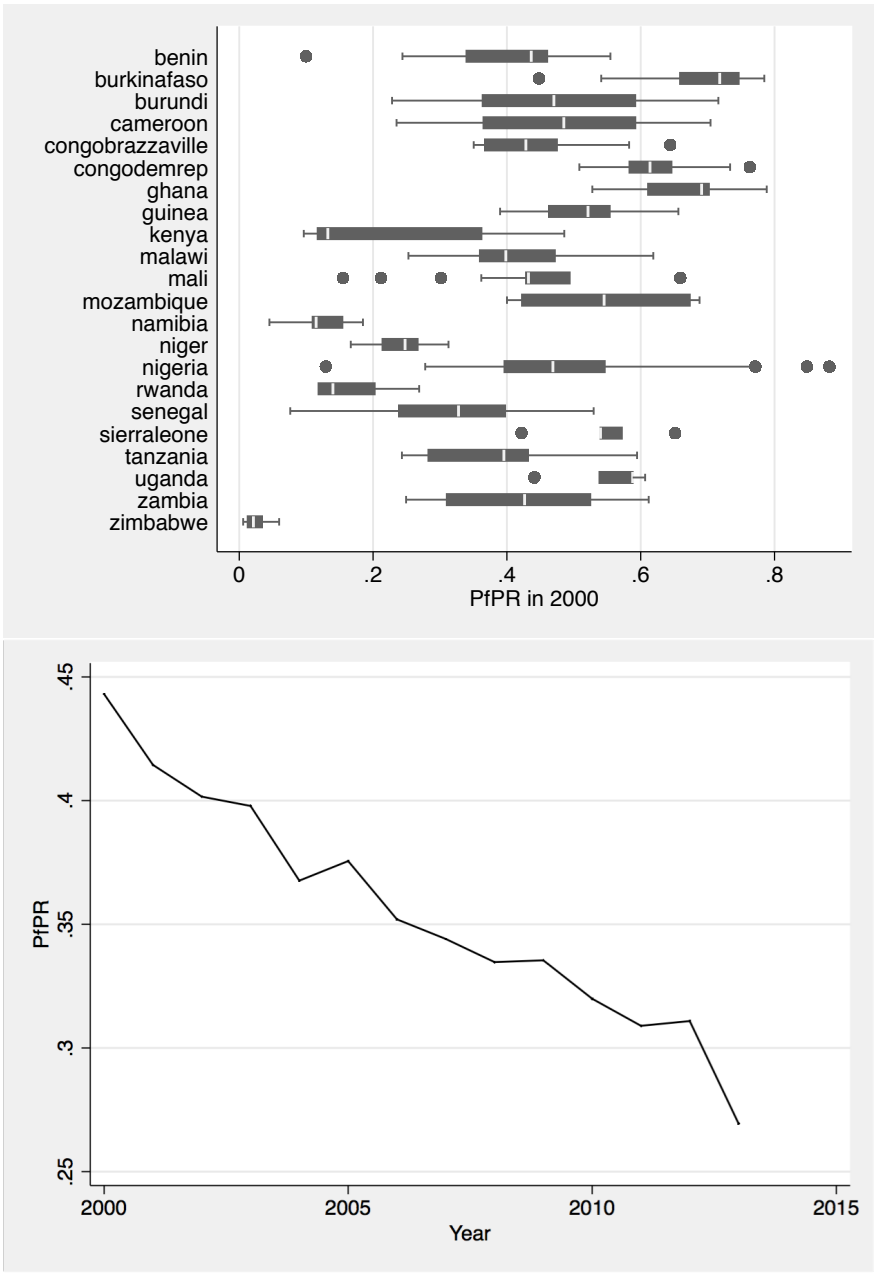


Figure 1.1: Malaria Endemicity in Sub-Saharan Africa, 2000–2013

Notes: Top panel: estimated *Plasmodium falciparum* parasite rate in children between the ages of 2 and 10 in 2000. Bottom panel: estimated *Plasmodium falciparum* parasite rate in children between the ages of 2 and 10 from 2000 to 2013. Underlying data from Malaria Atlas Project.

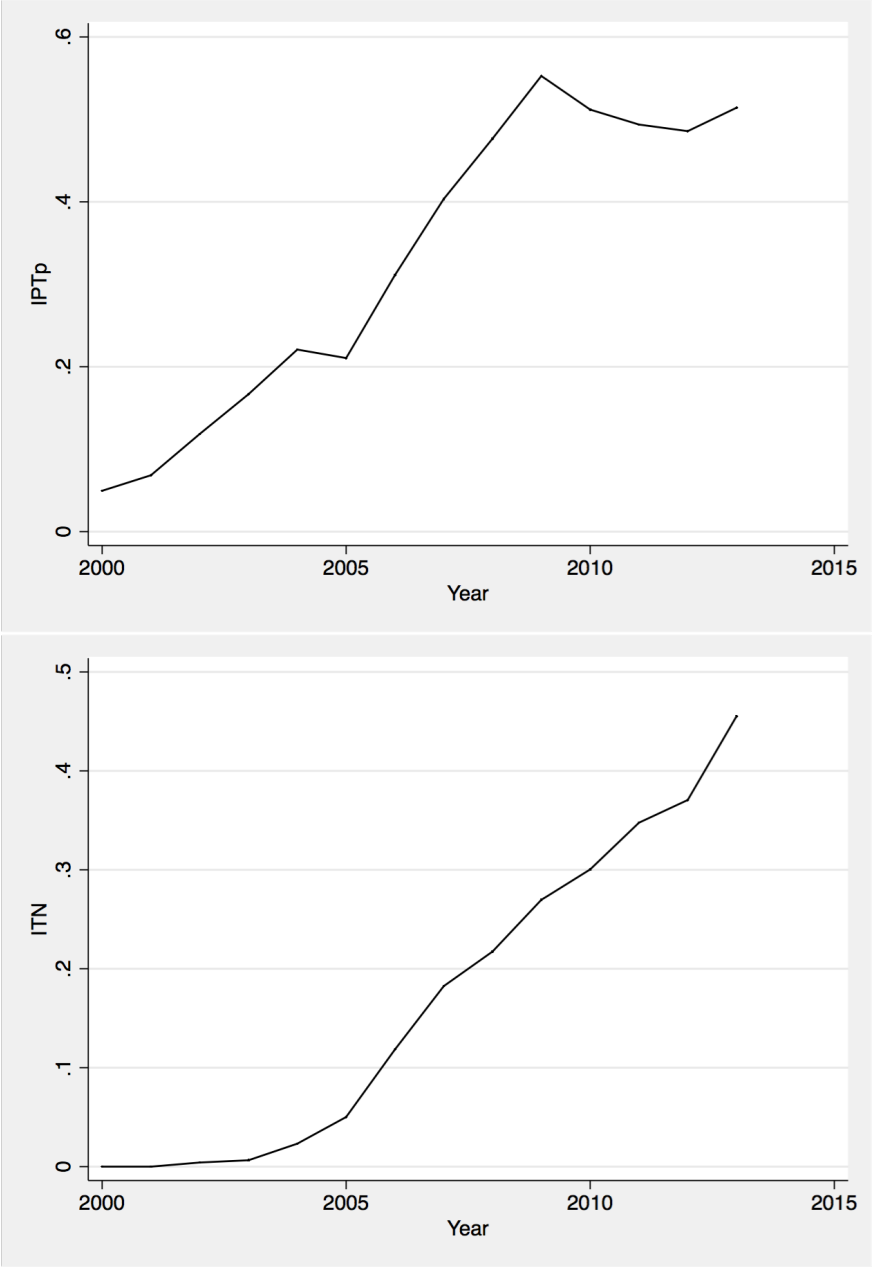


Figure 1.2: IPTp-SP Coverage and ITN Use in Sub-Saharan Africa, 2000–2013

Notes: Top panel: proportion of pregnant women reporting receipt of at least one dose of intermittent preventive treatment in pregnancy with sulfadoxine-pyrimethamine (IPTp-SP). Bottom panel: estimated proportion of individuals who slept under an insecticide-treated bed net (ITN) on any given night. Underlying data from Demographic and Health Surveys (IPTp) and Malaria Atlas Project (ITN).

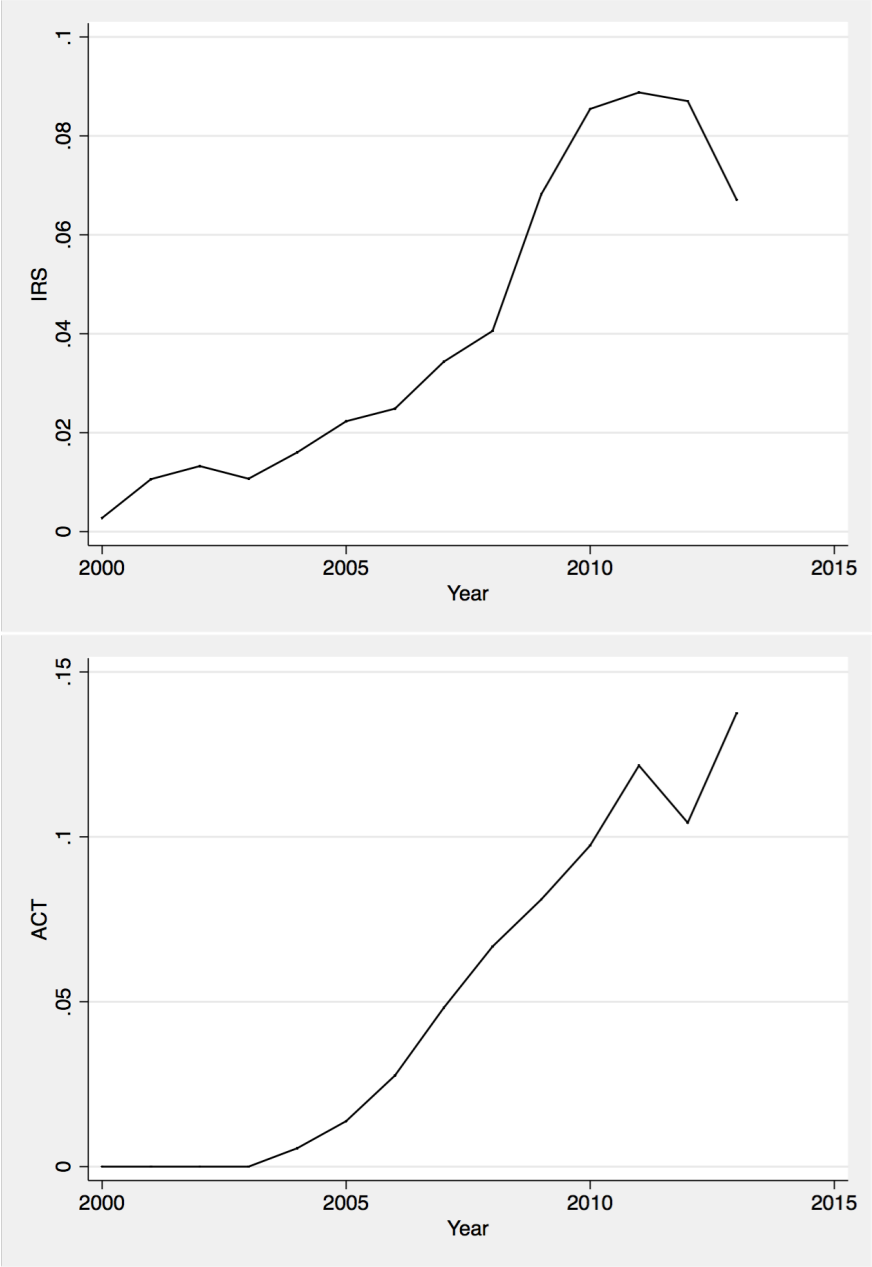


Figure 1.3: IRS and ACT Trends in Sub-Saharan Africa, 2000–2013

Notes: Top panel: estimated proportion of the population protected by indoor residual spraying of insecticides. Bottom Panel: estimated proportion of cases of fever in under-5 year olds that were treated with artemisinin-based combination therapy. Underlying data from Malaria Atlas Project.

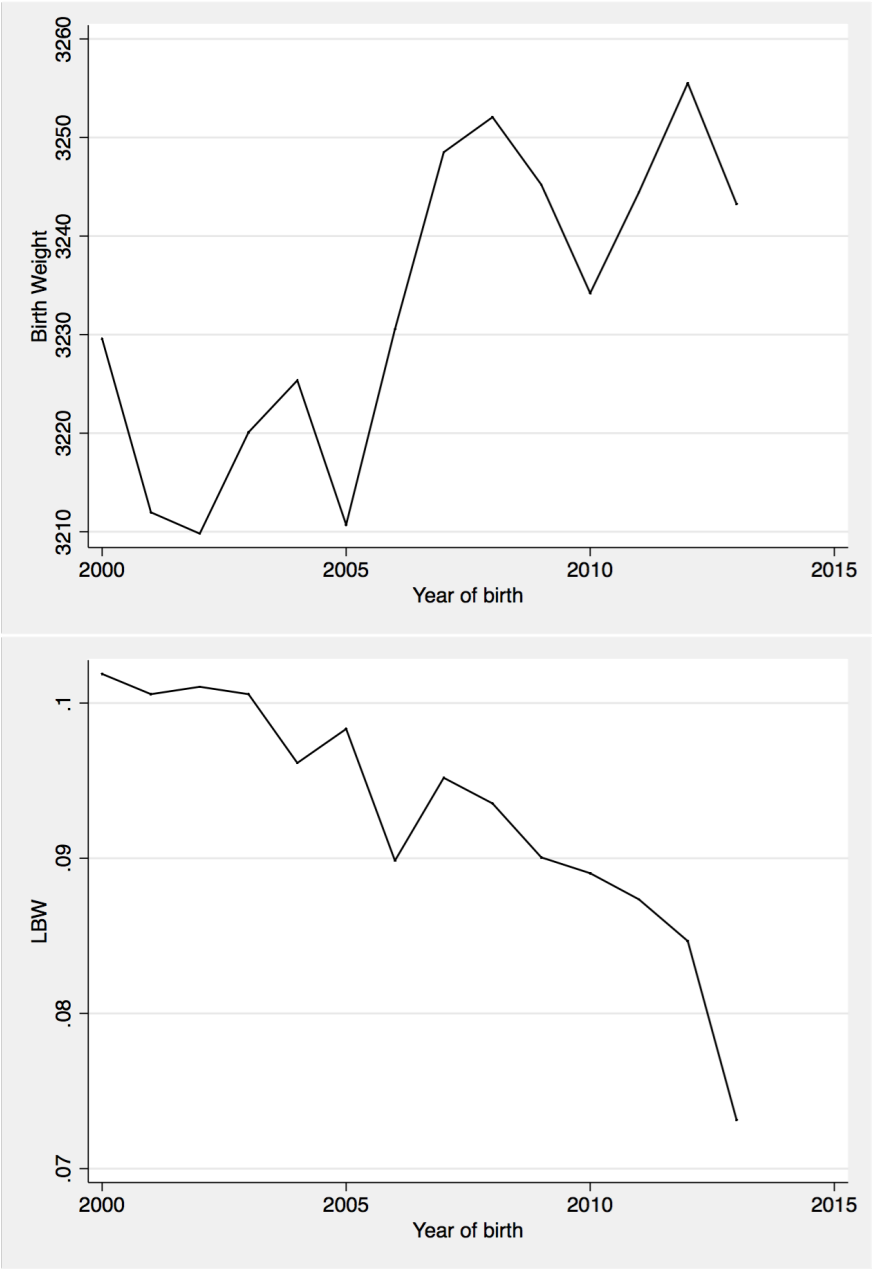


Figure 1.4: Birth Weight Trends in Sub-Saharan Africa, 2000–2013

Notes: Top panel: average weight of infants at birth in grams from 2000 to 2013. Bottom panel: proportion of infants with birth weight below 2,500 grams. Underlying data from Demographic and Health Surveys.

Table 1.1: Summary of Data Sources

Variables	Definitions	Sources and Years
Dependent Variables		
Birth weight (g)	Child's birth weight in grams	DHS, 2000–2013
Low birth weight	1 if child weighed less than 2,500 g at birth, 0 otherwise	DHS, 2000–2013
Small size at birth	1 if child was smaller than average in size at birth as reported subjectively by the respondent	DHS, 2000–2013
Very small size at birth	1 if child was very small in size at birth as reported subjectively by the respondent, 0 otherwise	DHS, 2000–2013
Malaria Endemicity		
$PfPR_{2-10}$ in 2000	*Plasmodium falciparum* parasite rate among children two to ten in 2000	MAP, 2000
Kiszewski et al. (2004) malaria stability index	Index of stability of malaria transmission	Kiszewski et al., 2004
Malaria Preventive Behaviors		
IPTp-SP: at least 1 dose	1 if mother of child received at least one dose of intermittent preventive treatment with sulfadoxine-pyrimethamine during pregnancy, 0 otherwise	DHS, 2000–2013
ITN usage	Share of individuals who slept under an insecticide-treated net in a given region during a given pregnancy	MAP, 2000–2013
IRS coverage	Share of individuals protected by indoor residual spraying of insecticides in a given country during a given pregnancy	MAP, 2000–2013
ACT coverage	Share of cases of fever in under-5 year olds that were treated with artemisinin-based combination therapy in a given country during a given pregnancy	MAP, 2000–2013
Individual- and Household-Level Controls		
Household in urban area	1 if household is located in urban area, 0 otherwise	DHS, 2000–2013
Wealth quintile	Household wealth quintile	DHS, 2000–2013
Mother has primary education	1 if mother has primary education, 0 otherwise	DHS, 2000–2013
Mother has at least secondary education	1 if mother has at least secondary education, 0 otherwise	DHS, 2000–2013
Mother's age at birth	Mother's age at birth in full years	DHS, 2000–2013
ANC visits: at most 3	1 if mother received antenatal care between 1 and 3 times during a given pregnancy, 0 otherwise	DHS, 2000–2013
ANC visits: 4 or more	1 if mother received antenatal care 4 or more times during a given pregnancy, 0 otherwise	DHS, 2000–2013
Male birth	1 if child is male, 0 otherwise	DHS, 2000–2013
Firstborn	1 if child's birth order to the mother is one, 0 otherwise	DHS, 2000–2013
Birth interval under 24 months	1 if preceding birth interval is under 24 months, 0 otherwise	DHS, 2000–2013

Notes: DHS – Demographic and Health Surveys; MAP – Malaria Atlas Project; Kiszewski et al., 2004 – Kiszewski, A., Mellinger, A., Spielman, A., Malaney, P., Sachs, S. E., & Sachs, J. (2004). A global index representing the stability of malaria transmission. *The American Journal of Tropical Medicine and Hygiene*, *70*(5), 486-498.

Table 1.2: Demographic and Health Surveys Data Sources

Country	No. observations	No. regions	DHS Surveys
Benin	17,672	12	DHS–2006, DHS–2011–12
Burkina Faso	16,412	13	DHS–2003, DHS–2010
Burundi	4,757	17	DHS–2010
Cameroon	12,028	10	DHS–2004, DHS–2011
Congo Brazzaville	7,405	11	DHS–2005, DHS–2011–12
Congo Democratic Republic	15,746	9	DHS–2007, DHS–2013–14
Ghana	7,284	10	DHS–2003, DHS–2008, DHS–2014
Guinea	8,841	8	DHS–2005, DHS–2012
Kenya	12,393	8	DHS–2003, DHS–2008–09, DHS–2014
Malawi	17,667	27	DHS–2004–05, DHS–2010
Mali	14,719	9	DHS–2006, DHS–2012–13
Mozambique	6,971	11	DHS–2011
Namibia	6,027	13	DHS–2006–07, DHS–2013
Niger	12,839	8	DHS–2006, DHS–2012
Nigeria	37,759	37	DHS–2003, DHS–2008, DHS–2013
Rwanda	5,292	5	DHS–2005
Senegal	22,536	11	DHS–2005, DHS–2010–11, DHS–2012–13, DHS–2014
Sierra Leone	10,139	4	DHS–2008, DHS–2013
Tanzania	10,523	9	DHS–2004–05, DHS–2010
Uganda	9,374	4	DHS–2006, DHS–2011
Zambia	12,806	9	DHS–2007, DHS–2013–14
Zimbabwe	8,055	10	DHS–2005–06, DHS–2010–11
Total: 22 countries	277,245	255	46 surveys

Notes: DHS – Demographic and Health Surveys.

Table 1.3: Sample Breakdown by Year of Birth

Year	No. observations
2000	4,520
2001	8,381
2002	14,912
2003	19,188
2004	21,810
2005	20,073
2006	19,777
2007	18,429
2008	23,658
2009	27,437
2010	32,961
2011	27,758
2012	24,094
2013	14,247
Total:	277,245

Notes: This sample breakdown is for the Tables 1.5 and 1.6 regression samples.

Table 1.4: Descriptive Statistics

	(1) All children	(2) Children weighed at birth	(3) Children not weighed at birth
	Mean (S. D.)	*Mean (S. D.)*	*Mean (S. D.)*
Birth weight (g)		3,226.557	
		(701.333)	
Low birth weight (<2,500 g)		0.092	
		(0.289)	
Small size at birth (smaller than average)	0.158	0.132	0.185
	(0.365)	(0.338)	(0.389)
Very small size at birth	0.048	0.035	0.062
	(0.214)	(0.185)	(0.240)
$PfPR_{2-10}$ in 2000	0.432	0.423	0.441
	(0.184)	(0.195)	0.171)
Kiszewski malaria stability index	16.149	14.730	17.662
	(9.343)	(9.383)	(9.059)
IPTp-SP: at least 1 dose	0.383	0.469	0.292
	(0.486)	(0.499)	(0.455)
ITN usage	0.195	0.215	0.173
	(0.190)	(0.194)	(0.185)
IRS coverage	0.050	0.064	0.034
	(0.103)	(0.117)	(0.083)
ACT coverage	0.062	0.071	0.052
	(0.087)	(0.095)	(0.077)
Household in urban area	0.300	0.433	0.159
	(0.458)	(0.495)	(0.366)
Wealth quintile	2.864	3.310	2.390
	(1.400)	(1.387)	(1.249)
Mother has primary education	0.324	0.358	0.288
	(0.468)	(0.479)	(0.453)
Mother has at least secondary education	0.225	0.335	0.109
	(0.418)	(0.472)	(0.311)
Mother's age at birth	27.550	27.253	27.864
	(7.049)	(6.814)	(7.280)
ANC visits: at most 3	0.354	0.347	0.361
	(0.478)	(0.476)	(0.480)
ANC visits: 4 or more	0.513	0.636	0.382
	(0.500)	(0.481)	(0.486)
Male birth	0.507	0.510	0.504
	(0.500)	(0.500)	(0.500)
Firstborn	0.199	0.240	0.155
	(0.399)	(0.427)	(0.362)
Birth interval under 24 months	0.127	0.108	0.147
	(0.333)	(0.311)	(0.354)
Observations	277,245	143,131	134,389

Notes: These summary statistics are for the Tables 1.5 and 1.6 regression samples. PfPR, ITN, IRS, and ACT information was drawn from the Malaria Atlas Project for the years 2000–2013. Kiszewski malaria stability index was drawn from Kiszewski et al., 2004. All other information was drawn from the 2003–2014 Demographic and Health Surveys (list of surveys used is presented in Table 1.2).

Table 1.5: Estimated Effects of Antimalarial Interventions on Birth Outcomes

	Firstborn children (columns 1 – 4)				*All children (columns 5 – 8)*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	LBW	Small	Very small	Birth weight	LBW	Small	Very small	Birth weight
IPTp-SP	-0.012**	-0.015***	-0.014***	-8.300	-0.010***	-0.013***	-0.013***	-5.096
	(0.005)	(0.005)	(0.004)	(10.996)	(0.003)	(0.003)	(0.003)	(6.524)
IPTp-SP x Malaria prevalence ($PfPR_{2-10}$)	-0.019	-0.012	0.035*	-80.951*	0.001	0.000	0.029**	-79.315**
	(0.024)	(0.024)	(0.019)	(48.328)	(0.014)	(0.014)	(0.013)	(32.953)
ITN	0.046	-0.017	-0.022	-194.098	0.022	-0.008	0.022	-115.455*
	(0.064)	(0.060)	(0.037)	(143.288)	(0.024)	(0.027)	(0.016)	(59.914)
ITN x Malaria prevalence ($PfPR_{2-10}$)	-0.106	0.027	-0.192	258.671	-0.172	0.175	0.033	468.861*
	(0.260)	(0.244)	(0.127)	(551.461)	(0.118)	(0.145)	(0.064)	(267.334)
IRS	0.090	-0.053	-0.061	-83.978	0.002	-0.014	0.014	191.530*
	(0.105)	(0.113)	(0.056)	(163.064)	(0.044)	(0.056)	(0.020)	(97.422)
IRS x Malaria prevalence ($PfPR_{2-10}$)	0.431*	0.394	0.182	-629.016	0.068	0.069	0.009	-320.276
	(0.236)	(0.271)	(0.144)	(459.901)	(0.108)	(0.144)	(0.063)	(264.232)
ACT	-0.005	0.105	0.118*	-265.812	-0.009	-0.030	0.003	-181.241
	(0.112)	(0.104)	(0.066)	(283.810)	(0.045)	(0.046)	(0.020)	(121.337)
ACT x Malaria prevalence ($PfPR_{2-10}$)	-0.345	-0.194	-0.057	1,009.177	-0.243	-0.189	0.020	745.234
	(0.508)	(0.473)	(0.292)	(871.488)	(0.232)	(0.228)	(0.128)	(500.163)
Observations	34,318	55,051	55,051	34,318	143,131	277,245	277,245	143,131
R-squared	0.049	0.060	0.055	0.089	0.029	0.052	0.043	0.081
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country x Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country x Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region x Trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Controls included but not shown: indicator for household in urban area, wealth quintile, mother's education dummies (primary education, at least secondary education), ANC dummies (at most 3 visits, 4 visits or more), mother's age at birth, indicator for male birth, indicator for first birth, indicator for birth interval under 24 months. Robust standard errors are clustered at the region level, and are in parentheses below OLS coefficients.
Asterisks denote statistical significance as follows: *** p-value ≤ 0.01, ** 0.01 ≤ p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

Table 1.6: Robustness Checks: Estimated Effects of Antimalarial Interventions on Birth Outcomes Using an Alternative Measure of Malaria Prevalence

	Firstborn children (columns 1 – 4)				*All children (columns 5 – 8)*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	LBW	Small	Very small	Birth weight	LBW	Small	Very small	Birth weight
IPTp-SP	-0.013***	-0.015***	-0.013***	-7.343	-0.010***	-0.013***	-0.012***	-5.916
	(0.005)	(0.005)	(0.004)	(10.929)	(0.002)	(0.003)	(0.002)	(6.529)
IPTp-SP x Kiszewski index	-0.002***	-0.000	-0.000	1.502	-0.001**	0.000	-0.000	0.506
	(0.001)	(0.001)	(0.000)	(1.151)	(0.000)	(0.000)	(0.000)	(0.625)
ITN	0.031	-0.031	0.002	-167.369	0.021	-0.003	0.021	-92.047
	(0.060)	(0.058)	(0.037)	(140.969)	(0.024)	(0.024)	(0.016)	(59.026)
ITN x Kiszewski index	0.001	0.002	0.003	-3.010	-0.004	0.002	0.002	1.833
	(0.006)	(0.005)	(0.003)	(8.931)	(0.002)	(0.002)	(0.001)	(4.285)
IRS	-0.034	-0.007	-0.129	163.260	-0.033	-0.081	-0.020	347.648*
	(0.139)	(0.137)	(0.087)	(284.009)	(0.068)	(0.081)	(0.030)	(183.513)
IRS x Kiszewski index	-0.007	0.012	-0.006	17.380	-0.003	-0.007	-0.004	13.449
	(0.011)	(0.011)	(0.007)	(24.746)	(0.005)	(0.007)	(0.003)	(15.449)
ACT	-0.030	0.134	0.128*	-177.091	-0.033	-0.078	-0.013	-78.934
	(0.148)	(0.114)	(0.074)	(352.820)	(0.058)	(0.050)	(0.023)	(145.638)
ACT x Kiszewski index	-0.003	0.006	0.004	10.523	-0.005	-0.008*	-0.002	14.951
	(0.012)	(0.009)	(0.006)	(24.724)	(0.005)	(0.004)	(0.002)	(11.308)
Observations	34,318	55,051	55,051	34,318	143,131	277,245	277,245	143,131
R-squared	0.049	0.060	0.055	0.089	0.029	0.052	0.043	0.081
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country x Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country x Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region x Trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Controls included but not shown: indicator for household in urban area, wealth quintile, mother's education dummies (primary education, at least secondary education), ANC dummies (at most 3 visits, 4 visits or more), mother's age at birth, indicator for male birth, indicator for first birth, indicator for birth interval under 24 months. Robust standard errors are clustered at the region level, and are in parentheses below OLS coefficients.
Asterisks denote statistical significance as follows: *** p-value ≤ 0.01, ** 0.01 ≤ p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

Table 1.7: Falsification Checks: Estimated Effects of Antimalarial Interventions on Nutrition and General Welfare

	Nutritional factors (columns 1 – 4)				*General welfare factors (columns 5 – 6)*	
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Meat	Eggs	Potatoes	Mother's BMI	Electricity	Television
IPTp-SP	0.016	0.015	0.010	3.610	0.001	-0.004
	(0.015)	(0.010)	(0.017)	(4.521)	(0.004)	(0.004)
IPTp-SP x Malaria prevalence	-0.047	0.034	-0.093	28.460	-0.028	-0.008
	(0.065)	(0.056)	(0.083)	(22.713)	(0.022)	(0.021)
ITN	0.064	-0.191	-0.489	-50.208	-0.048	-0.038
	(0.436)	(0.246)	(0.407)	(63.296)	(0.055)	(0.061)
ITN x Malaria prevalence	1.583	1.897	0.677	90.141	-0.068	-0.019
	(1.993)	(1.174)	(2.066)	(246.959)	(0.255)	(0.211)
IRS	1.505	1.233	-0.808	81.382	-0.041	0.035
	(1.268)	(0.902)	(1.395)	(106.581)	(0.098)	(0.089)
IRS x Malaria prevalence	3.543	2.697	-2.066	288.384	0.133	-0.140
	(3.148)	(2.230)	(3.445)	(291.305)	(0.236)	(0.216)
ACT	0.144	-0.113	0.004	-29.622	-0.079	-0.048
	(0.376)	(0.192)	(0.372)	(107.073)	(0.090)	(0.105)
ACT x Malaria prevalence	0.045	-1.592	-1.062	-931.239*	0.421	-0.152
	(2.422)	(1.274)	(2.282)	(545.894)	(0.453)	(0.383)
Observations	6,997	6,987	7,003	39,270	51,912	53,635
R-squared	0.235	0.145	0.202	0.168	0.562	0.505
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Country x Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Country x Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Region x Trend	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Controls included but not shown: indicator for household in urban area, wealth quintile, mother's education dummies (primary education, at least secondary education), ANC dummies (at most 3 visits, 4 visits or more), mother's age at birth, indicator for male birth. Robust standard errors are clustered at the region level, and are in parentheses below OLS coefficients.
Asterisks denote statistical significance as follows: *** p-value ≤ 0.01, ** 0.01 ≤ p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

Table 1.8: Subsample Analysis: Estimated Effects of Antimalarial Interventions on Birth Outcomes of Firstborn Boys and Non-Firstborn Girls

	Firstborn Boys (columns 1 – 4)				*Non-firstborn Girls (columns 5 – 8)*			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	LBW	Small	Very small	Birth weight	LBW	Small	Very small	Birth weight
IPTp-SP	-0.010*	-0.014**	-0.016***	-19.924	-0.012***	-0.011***	-0.010***	2.812
	(0.006)	(0.006)	(0.004)	(16.365)	(0.004)	(0.004)	(0.003)	(10.407)
IPTp-SP x Malaria prevalence	-0.011	0.013	0.039**	-96.850	-0.011	-0.013	0.024*	-63.654
	(0.027)	(0.029)	(0.019)	(68.967)	(0.020)	(0.017)	(0.014)	(50.335)
ITN	-0.075	-0.079	-0.083**	-88.427	0.023	-0.020	0.019	-178.768*
	(0.073)	(0.064)	(0.038)	(156.366)	(0.045)	(0.039)	(0.025)	(101.069)
ITN x Malaria prevalence	0.100	0.109	0.092	-228.262	-0.315*	0.346*	0.122	646.595
	(0.183)	(0.184)	(0.112)	(358.676)	(0.188)	(0.184)	(0.105)	(447.805)
IRS	0.048	-0.349**	-0.104	498.486*	0.015	0.049	0.054	276.416*
	(0.123)	(0.146)	(0.073)	(273.536)	(0.073)	(0.087)	(0.038)	(163.668)
IRS x Malaria prevalence	0.056	-0.179	-0.037	-166.657	-0.195	-0.009	-0.067	159.360
	(0.315)	(0.349)	(0.173)	(701.281)	(0.201)	(0.208)	(0.104)	(406.742)
ACT	-0.138	0.034	0.058	0.903	-0.058	-0.077	0.014	-31.677
	(0.154)	(0.139)	(0.109)	(387.021)	(0.094)	(0.076)	(0.037)	(201.651)
ACT x Malaria prevalence	-0.450	-0.079	-0.171	873.585	-0.336	-0.008	0.028	918.757
	(0.369)	(0.409)	(0.238)	(826.934)	(0.388)	(0.355)	(0.211)	(861.880)
Observations	17,531	27,987	27,987	17,531	53,287	109,585	109,585	53,287
R-squared	0.057	0.058	0.056	0.094	0.035	0.057	0.050	0.076
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Controls included but not shown: indicator for household in urban area, wealth quintile, mother's education dummies (primary education, at least secondary education), ANC dummies (at most 3 visits, 4 visits or more), mother's age at birth. Robust standard errors are clustered at the region level, and are in parentheses below OLS coefficients.

Asterisks denote statistical significance as follows: *** p-value ≤ 0.01, ** 0.01 ≤ p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

CHAPTER 2:

MEDICAL MARIJUANA LAWS AND EARLY-LIFE HEALTH

2.1 INTRODUCTION

Although possession and sale of marijuana for any purpose remain illegal at the U.S. federal level, as of June 2017, medical marijuana laws (MMLs) which liberalize the cultivation, possession, and use of cannabis for allowable medical purposes have been adopted by 29 states and the District of Columbia. With the expansion of state-level legislation allowing for medical marijuana use and the corresponding ongoing debate regarding drug policy, there has been a growing interest in investigating and quantifying both direct and indirect effects of the implementation of MMLs.

Many recent studies have estimated the effects of MMLs on a variety of economic and public health outcomes including marijuana use among adults, alcohol consumption, tobacco use, hard drug use, prescription medication use, labor market outcomes, depression, body weight, health of older adults, and other measures and indicators (Anderson et al., 2013; Anderson et al., 2014; Anderson et al., 2015; Bradford and Bradford, 2016; Choi et al., 2016; Chu, 2014; Chu, 2016; Pacula et al., 2014; Sabia and Nguyen, 2016; Sabia et al., 2017, etc.). However, to date little is known about the effects of MMLs on early-life health.

The effect of MMLs on early-life health is theoretically ambiguous. If MMLs allow pregnant women to effectively treat qualifying physical or mental conditions which would otherwise result in poor birth outcomes, MMLs could improve neonatal health indicators. If the

effects of MMLs spill over into the recreational market and increase non-medicinal marijuana use among pregnant women, MMLs could worsen birth outcomes. MMLs can also have an impact on birth outcomes through their effects on alcohol, tobacco, or other drugs, with the direction of the effect depending on whether marijuana and other risky behaviors are substitutes or complements. Furthermore, the effects of MMLs on birth outcomes may display significant heterogeneity by age, race, or other socio-demographic characteristics.

Using restricted individual-level natality data (with geographic detail) from National Center for Health Statistics (NCHS) from 1990 to 2013 and taking advantage of the geographic and temporal variation in the implementation of MMLs, this chapter aims at estimating the effects of state-level marijuana legislation on early-life health, particularly birth outcomes, such as birth weight, length of gestation, and Apgar scores in a difference-in-differences framework. I find that while MMLs have no impact on birthweight or gestation, they are associated with decreases in Apgar scores and increased likelihood of severe distress and mild distress births.

Analysis of both direct and indirect effects of MMLs provides means to monitor the success of public policy in achieving its goals and targets. The impact of MMLs should be robustly evaluated to inform optimal policy strategy for the future. This study provides new information to the current policy debate surrounding marijuana liberalization legislation.

The outline of this chapter is as follows. Section 2.2 provides background on MMLs in the United States, an overview of prior economic literature, a discussion of potential mechanisms linking MMLs and birth outcomes, and a summary of the empirical evidence on the effect of marijuana use in pregnancy. Section 2.3 presents the data and some descriptive statistics. Section 2.4 discusses the empirical strategy and the identification assumptions. Main results, robustness checks and subsample analysis are reported in Section 2.5. Section 2.6 concludes.

2.2 BACKGROUND

2.2.1 Medical Marijuana Laws in the United States

At the federal level, manufacture, importation, possession, use, and distribution of controlled substances is regulated by The Controlled Substances Act of 1970, a federal drug policy that categorizes drugs into five "Schedules" or classifications based on their potential for abuse, status in international treaties, any medical benefits they may provide, and safety. Marijuana remains classified as a Schedule I drug, which means that it is deemed to have "no currently acceptable medical use in treatment in the United States," a high potential for abuse, and "a lack of accepted safety for use... under medical supervision" (O'Keefe, 2013). Other Schedule I drugs include heroin, ecstasy, and LSD. For comparison, cocaine and morphine are Schedule II drugs, Vicodin is a Schedule III drug, Ambien, Xanax, and Valium are Schedule IV drugs, and Robitussin is a Schedule V drug.

Despite this, as of June 2017, MMLs which liberalize the cultivation, possession, and use of cannabis for allowable medical purposes have been adopted by 29 states and the District of Columbia. State laws differ in terms of the specific conditions and illnesses that are accepted for medical marijuana use. Frequently approved conditions include chronic pain, nausea, cachexia (weakening or wasting of the body), wasting syndrome resulting from HIV, glaucoma, AIDS, and cancer (Bradford and Bradford, 2016). States that legalized medical marijuana between 1990 and 2013 are shown in Figure 2.1. Table 2.1 presents dates of passage of original legislation and effective dates of the state medical marijuana laws.

2.2.2 Prior Economic Studies on the Effects of Medical Marijuana Laws

With the expansion of state-level legislation allowing for medical marijuana use and the corresponding ongoing debate regarding drug policy, there has been a growing interest in investigating and quantifying both direct and indirect effects of the implementation of MMLs. In particular, the effects of MMLs have been an actively researched topic within economic literature.

Economic studies have investigated the effect of MMLs on prescription medication use (Bradford and Bradford, 2016), recreational marijuana use (Anderson et al., 2015; Pacula et al., 2015; Wen et al., 2015; Chu, 2014), use of other substances, such as alcohol (Wen et al., 2015; Anderson et al., 2013), tobacco (Choi et al., 2016), and hard drugs (Wen et al., 2015; Chu, 2015), labor market outcomes, such as labor supply (Nicholas and Maclean, 2016), earnings (Sabia and Nguyen, 2016), and sickness absences (Ullman, 2016), health outcomes, such as body weight (Sabia et al., 2017), opioid addictions and opioid overdose deaths (Powell et al., 2015), suicides (Anderson et al., 2014), and traffic fatalities (Anderson et al., 2013), and even seatbelt use (Adams et al., 2017). Overall, these studies suggest that MMLs increase recreational use of marijuana among adults but not teenagers, decrease alcohol, tobacco, and heroin, but not cocaine use, decrease BMI, suicides, and traffic fatalities, and improve labor market outcomes for older adults.

Despite a growing body of literature on the impact of MMLs, little is known about the effect of these laws on early-life health.

2.2.3 Mechanisms Linking Medical Marijuana Laws and Birth Outcomes

The effect of MMLs on early-life health is theoretically ambiguous. If MMLs allow pregnant women to effectively treat qualifying physical or mental conditions which would otherwise result in poor birth outcomes, MMLs could improve them. MMLs could increase recreational marijuana use by increasing availability and access or by changing perceived harmfulness, as it can now be viewed as a medicine (Pacula et al., 2015). If the effects of MMLs spill over into the recreational market and increase non-medicinal marijuana use among pregnant women, MMLs could worsen birth outcomes. MMLs can also have an impact on birth outcomes through their effects on alcohol, tobacco, or other drugs, with the direction of the effect depending on whether marijuana and other risky behaviors are substitutes or complements. Furthermore, the effects of MMLs on birth outcomes may display significant heterogeneity by age, race, or other socio-demographic characteristics.

2.2.4 Marijuana Use and Birth Outcomes

In the United States, marijuana is the most widely used drug during pregnancy with estimated usage rates varying from as low as 2% to as high as 11% (Chabarria et al., 2016) and continuing to increase (Brown et al., 2017). Despite a large volume of literature on the effects of marijuana use in pregnancy[1], the results of the existing studies are conflicting, and a scientific consensus on the risks of marijuana has not been achieved.

Given the passage of cannabinoids to the placenta, a link between marijuana use and adverse neonatal and later-life outcomes is biologically plausible. Marijuana is thought to affect glucose and insulin regulation and thus has a potential to affect fetal growth trajectory (Metz and

[1] See Gunn et al. (2016) for a systematic review and meta-analysis and Metz and Stickrath (2015) for a clinician-oriented review.

Stickrath, 2015). Furthermore, marijuana may affect fetal brain growth and neurodevelopment through its interaction with the endocannabinoid system (Volkow et al., 2017). Despite this, the evidence of the effects of marijuana use in pregnancy on various measures of infant health is mixed. While many studies find associations between maternal marijuana use and fetal growth restriction, preterm birth, increased placement in NICU/ICU, and other adverse neonatal outcomes, many others report no such associations, and some even find beneficial effects of prenatal marijuana use. Overall, the effects of cannabis on early-life outcomes remain largely unknown due to confounding factors such as tobacco, alcohol, and other drug exposure, as well as socio-demographic characteristics not considered by existing studies (Gunn et al., 2016).

Given the uncertainty about the risks of marijuana use in pregnancy due to insufficient data and specifically citing the growing number of states legalizing marijuana for medicinal and recreational purposes as a concern, the American College of Obstetricians and Gynecologists (ACOG) recommends that pregnant women and women contemplating pregnancy be discouraged from using marijuana. Furthermore, ACOG discourages obstetrician-gynecologists from recommending the use of medical marijuana during preconception, pregnancy, and lactation and suggests that pregnant women or women contemplating pregnancy discontinue use of marijuana for medicinal purposes in favor of alternative therapies for which there are better pregnancy-specific safety data. (ACOG, 2015).

2.3 DATA CONSTRUCTION AND DESCRIPTIVE STATISTICS

2.3.1 NCHS Natality Data

This chapter uses information on individual birth records from the Centers for Disease Control and Prevention's National Center for Health Statistics' (NCHS) U.S. Natality Files for years

1990 – 2013. NCHS receives detailed information on all live births, prepared from individual records submitted by hospitals and processed by each registration area, through the Vital Statistics Cooperative Program.[2] [3] Birth data available in the U.S. Natality Files are based on 100% of the birth certificates registered in the 50 States and the District of Columbia.[4] [5] Births to nonresidents of the United States are excluded from the analysis. Births occurring to U.S. citizens outside of the United States are not included in the Natality Files.

Information on each birth contains detailed characteristics of the newborn, including time and place of birth, birth weight, gestation, Apgar score, plurality, abnormal conditions, and congenital anomalies, demographic characteristics of the mother, such as age, race, Hispanic origin, marital status, and education, along with medical and health information on the pregnancy and delivery. This data is obtained directly from the mother, as well as the medical records of the mother and infant.[6]

[2] All states require birth certificates to be filed for all live births regardless of length of gestation or birth weight, and Federal law mandates national compilation and publication of births and other vital statistics data. If a delivery results in a fetus that shows no evidence of life (no heartbeat, respiration, voluntary movement of muscles, or any other evidence of life), a fetal death report is filed.

[3] All 50 U.S. states, the District of Columbia, the independent registration area of New York City, and U.S. territories (Puerto Rico, the U.S. Virgin Islands, Guam, American Samoa, and the Commonwealth of the Northern Mariana Islands) are considered registration areas for the purpose of collecting vital statistics data.

[4] More than 99% of births occurring in the United States are registered. For more information on completeness of registration, see user guides for the natality public use files, available at: https://www.cdc.gov/nchs/data_access/vitalstatsonline.htm.

[5] While New York City is considered a distinct registration area, separate from the state of New York, for the purposes of this chapter, New York City births are merged with births that occurred in the rest of the New York state. U.S. territories data are available in a separate set of files and are not used in this chapter.

[6] Figures C1 and C2 in the Appendix contain images of the U.S. Standard Certificates of Birth revised and adopted in 1989 and 2003, respectively. Table C1 in the Appendix presents the timeline of the implementation of the 2003 revision by the 50 U.S. states and the District of Columbia. While many data items are common to both 1989 and 2003 standard birth certificates, several items were substantially modified, removed altogether, or introduced for the first time in the 2003 revision. This chapter uses only those data items which are directly comparable across the two standard birth certificates, as well as items which could be sufficiently harmonized.

U.S. Natality Files are publicly available at the official NCHS website,[7] however, beginning with the 2005 data year, no longer include geographic detail. Restricted data files with geographic identifiers are available to researchers upon request following a review by the National Association for Public Health Statistics and Information Systems (NAPHSIS).[8]

The primary outcomes of interest for this analysis are birth weight, gestation, and Apgar score. In order to capture the potential effect of MMLs on these outcomes along their distributions, I define the following outcome variables: 1) birth weight in grams; 2) indicator for extremely low birth weight (infant born weighing less than 1,000 grams); 3) indicator for very low birth weight (infant born weighing less than 1,500 grams); 4) indicator for low birth weight (infant born weighing less than 2,500 grams); 5) gestational age in weeks; 6) indicator for preterm birth (gestational age less than 37 weeks); 7) indicator for late preterm birth (gestational age greater than 34 weeks but less than 37 weeks); 8) indicator for early term birth (gestational age greater than 37 weeks but less than 39 weeks); 9) 5-minute Apgar score (Apgar score between 0 and 10); 10) indicator for severe distress at birth (Apgar score between 0 and 3); 11) indicator for mild distress at birth (Apgar score between 4 and 6).

My analysis makes use of a rich set of individual-level controls available in the U.S. Natality Files that may be correlated with both the implementation of MMLs and infant health outcome variables. In particular, I use the following variables: sex of infant (1 if male, 0 if female), dummies for month of birth (February – December; January is the omitted category), dummies for live birth order (1–7; 8+ is the omitted category), age of mother, age of mother squared, indicator for Hispanic origin of mother, dummies for race of mother (Black, Native

[7] Available at: https://www.cdc.gov/nchs/data_access/vitalstatsonline.htm.

[8] For more information on the NCHS data release and access policy, including procedures for requesting data files with geographic detail, see: https://www.cdc.gov/nchs/nvss/dvs_data_release.htm.

American/Alaskan Native, Asian/Pacific Islander; White is the omitted category), indicator for marital status of mother (1 if married, 0 otherwise), dummies for education of mother (8th grade or less; some high school; some college; bachelor's degree; master's, doctorate, or professional degree; high school graduate is the omitted category).[9]

I restrict my analysis to singleton births for which at least one health outcome of interest (birth weight, gestation, and/or Apgar score) is available. This yields the maximum sample size of 94,101,306. The sample breakdowns by year of birth and state are presented in Tables 2.2 and 2.3, respectively. Descriptive statistics for the full sample are reported in Table 2.4.

2.3.2 State-Level Medical Marijuana Laws

This chapter makes use of effective dates of state MMLs from the National Conference of State Legislatures,[10] ProCon.org,[11] and the National Organization for the Reform of Marijuana Laws[12] to identify treated and untreated births. I match MMLs to the NCHS natality data based on the year when the law went into effect. For the main analysis, I construct an indicator variable for whether a state had an MML in effect in the year of birth of a child. For robustness checks, I create 3 years of leads and 5 years of lags for the MMLs.

[9] I do not use the information on prenatal care, alcohol consumption, and smoking as these behaviors may be plausibly endogenous with respect to MMLs, and including them in the analysis may introduce bias in the estimation of the effects of MML on birth outcomes.

[10] Accessed at: http://www.ncsl.org/research/health/state-medical-marijuana-laws.aspx.

[11] Accessed at: http://medicalmarijuana.procon.org/view.resource.php?resourceID=000881.

[12] Accessed at: http://norml.org/states.

2.3.3 State-Level Control Variables

In addition to the MMLs, my analysis utilizes controls for time-varying state-level policies and characteristics that may be correlated with both the implementation of MMLs and infant health outcome variables. In particular, I control for whether a state has decriminalized marijuana (from the Marijuana Policy Project[13]), whether a state has legalized recreational marijuana (from the National Organization for the Reform of Marijuana Laws[14]), unemployment rate (from the Bureau of Labor Statistics Local Area Unemployment Statistics Database), cigarette excise taxes (from the Tax Foundation[15]), minimum wages (from the Wage and Hour Division of the United States Department of Labor[16]), state earned income tax credit programs (EITC), whether the state EITC is refundable, and the generosity of the state EITC measured as a percentage of federal credit (from Tax Credits for Working Families,[17] Tax Policy Center of the Urban Institute and Brookings Institution,[18] and the National Conference of State Legislatures[19]).

2.4 RESEARCH STRATEGY

In keeping with the MML literature, I explore the relationship between MMLs and early life health measures using a difference-in-differences estimation framework which exploits both temporal and geographic variation in the implementation of MMLs.

[13] Accessed at: https://www.mpp.org/issues/decriminalization/state-laws-with-alternatives-to-incarceration-for-marijuana-possession/.

[14] Accessed at: http://norml.org/states.

[15] Accessed at: https://taxfoundation.org/individual-consumption-taxes/excise-taxes/cigarette-and-tobacco-taxes/.

[16] Accessed at: https://www.dol.gov/whd/state/stateMinWageHis.htm.

[17] Accessed at: http://www.taxcreditsforworkersandfamilies.org/state-tax-credits/.

[18] Accessed at: http://www.taxpolicycenter.org/statistics/state-eitc-based-federal-eitc/.

[19] Accessed at: http://www.ncsl.org/research/labor-and-employment/earned-income-tax-credits-for-working-families.aspx.

First, following Anderson et al. (2013), I begin with the baseline equation of the following form:

$$Y_{ist} = \beta_0 + \beta_1 MML_{st} + X_{st}\beta_2 + Z_{ist}\beta_3 + \nu_s + \omega_t + \varepsilon_{ist}\,, \quad (1)$$

where Y_{ist} measures the birth outcome (birth weight, low birth weight status, length of gestation, Apgar score, etc.) for a child i born in year t to a mother residing in state s, MML_{st} is an indicator for whether state s had an MML law in effect in year t, X_{st} is a vector of time-varying state controls, Z_{ist} is a vector of individual-level controls, ν_s is a state fixed effect (to control for permanent differences in outcomes across states), ω_t is a year fixed effect (to control for trends in outcomes across years in all states), and ε_{ist} is the disturbance.

Additionally, following Anderson et al. (2015), Anderson et al. (2014), Sabia and Nguyen (2016), and Choi et al. (2016), I experiment with specifications that include state-specific linear trends ($\nu_s \times t$) as supplementary right hand-side variables:

$$Y_{ist} = \beta_0 + \beta_1 MML_{st} + X_{st}\beta_2 + Z_{ist}\beta_3 + \nu_s + \omega_t + \nu_s \times t + \varepsilon_{ist}\,. \quad (2)$$

These time trends are intended to capture difficult to measure factors such as attitudes that might have evolved differently over time in states that legalized medical marijuana compared with states that did not.

Finally, following Chu (2014), Chu (2015), and Sabia et al. (2017), I add state-specific quadratic time trends ($\nu_s \times t^2$):

$$Y_{ist} = \beta_0 + \beta_1 MML_{st} + X_{st}\beta_2 + Z_{ist}\beta_3 + \nu_s + \omega_t + \nu_s \times t + \nu_s \times t^2 + \varepsilon_{ist}\,. \quad (3)$$

I estimate equations (1) – (3) using ordinary least squares and cluster the standard errors at the state level to allow for arbitrary correlation among observations in the same state over time (Bertrand et al., 2004).

The key coefficient of interest in equations (1) – (3) is β_1 which captures the net effect of the MMLs on birth outcomes. It is identified under the assumption that birth outcomes would have followed the same trends in states which legalized medical marijuana and states which did not, had MMLs not been implemented. Inclusion of state-specific linear and quadratic time trends in specifications (2) and (3) relaxes this assumption by allowing for differential trends in outcomes of interest. Therefore, these models can account for empirically important unobserved cross-state heterogeneity in both levels and trends. Additionally, I test for differential trends in birth outcomes by estimating specifications that include leads of MMLs on the right-hand side of the estimating equations.

2.5 RESULTS

2.5.1 Main Analysis of the Effect of Medical Marijuana Laws on Birth Outcomes

I begin the analysis by investigating whether there were any changes in the state-average birth outcomes after MMLs had been passed. Tables 2.5, 2.6, and 2.7 present state-level difference-in-differences estimates of the effect of MMLs on birth weight, gestation, and Apgar scores, respectively. In each of the three tables, each column represents a result from a separate regression. Columns (1), (4), (7), and (10) do not include trends, columns (2), (5), (8), and (11) contain state-specific linear trends, and columns (3), (6), (9), and (12) add state-specific quadratic trends. I find that MMLs did not result in changes in the state-average birth outcomes.

Next, I take advantage of the availability of the micro-level data and conduct individual-level analysis of the effect of MMLs on birth outcomes. Tables 2.8, 2.9, and 2.10 report individual-level difference-in-differences estimates of the effect of MMLs on birth weight, gestation, and Apgar scores, respectively. In each of the three tables, estimates in Panel A are

based on specifications that only use state and year fixed effects, estimates in Panel B are based on specifications that add individual-level controls but not state-level controls, and estimates in Panel C are based on specifications that include both individual and state-level controls. In every panel, each column represents a result from a separate regression. Columns (1), (4), (7), and (10) do not include trends, columns (2), (5), (8), and (11) contain state-specific linear trends, and columns (3), (6), (9), and (12) add state-specific quadratic trends.

Table 2.8 does not present any evidence to support the hypothesis that MMLs have a negative impact on birth weight. The estimates of β_1 in regressions with birth weight in grams as the dependent variable are statistically significant at conventional levels only in specifications without state-specific trends (column (1)) and are, in fact, positive. In specifications that include state-specific linear or quadratic trends (columns (2) and (3)), the estimates of β_1 are statistically insignificant at conventional levels and are never negative. Furthermore, in regressions with indicators for extremely low birth weight, very low birth weight, and low birth weight as outcome variables, the estimates of β_1 are not statistically significant, and never different from zero.

Similarly, Table 2.9 provides no indication of negative effects of MMLs on gestation. In specifications without state-specific trends, the estimates of β_1 in regressions with gestation in weeks as the dependent variable are statistically significant at conventional levels and never negative (column (1)), although these results are sensitive to the inclusion of trends. In specifications that include state-specific trends, the estimate of β_1 is only statistically significant at the 10% level in Panel C, column 2, and is still positive. Regressions for preterm, late preterm, and early term births as outcomes yield estimates of β_1 that are either statistically significant and negative (Panel C, column (4); all Panels, columns (7), (10), and (11)), or statistically

insignificant and equal to zero. In specifications that include state-specific quadratic time trends, the estimates of β_1 are not statistically significant at conventional levels.

Finally, Table 2.10 does not provide strong and consistent evidence of any negative effects of MMLs on Apgar scores. Although coefficients on MML indicators are negative and statistically significant in Panel C, columns (1) and (2), which would suggest that MMLs decrease Apgar scores, these results are not only very small in magnitude (for instance, in Panel C, column 2, the estimated effect is a 0.9% decrease in Apgar scores, -0.078/8.903=-0.009) but also no longer hold when state-specific quadratic trends are added to the regressions. Similarly, columns (4), (5), (7), and (8) in Panel C suggest that MMLs increased the likelihood of severe distress and mild distress births, however these results do not withstand the inclusion of state-specific quadratic trends.

Taken together, the results from the main analysis do not support the hypothesis that MMLs have a negative impact on birth weight or gestation, however the estimated effects of MMLs on Apgar scores are specification-dependent and require further investigation.

2.5.2 Lagged Effects of Medical Marijuana Laws on Birth Outcomes

It is plausible that changes in birth outcomes may take time to occur. In order to investigate possible lagged effects of MMLs, I replace the indicator for MMLs in specifications (1), (2), and (3) with a contemporaneous MML indicator (takes value 1 in the year of law change only) and 5 lags of the laws. The estimates of lagged effects of MMLs on birth weight, gestation, and Apgar scores are reported in Tables 2.11, 2.12, and 2.13, respectively. In every table, each column represents a result from a separate regression. All specifications include state and year fixed effects, as well as individual- and state-level controls. Columns (1), (4), (7), and (10) do not

include trends, columns (2), (5), (8), and (11) contain state-specific linear trends, and columns (3), (6), (9), and (12) add state-specific quadratic trends.

Table 2.11 provides no evidence of negative lagged effects of MMLs on birth weight across the distribution. The estimates of the coefficients on the MML lags are only statistically significant in column (1) and are, in fact, positive.

In Table 2.12, specifications with linear state-specific trends suggest that MMLs decrease the likelihood of early term births by 2.4% in the year of law change (-0.006/0.246=-0.024) and by 2.8% (-0.007/0.246=-0.028) in the year following the law change without a corresponding increase in the likelihood of preterm or late preterm births, as well as increase gestational age by 0.2% (0.093/38.870=0.002) 5 years after a law goes into effect. These findings, however, no longer hold following the inclusion of the state-specific quadratic trends. Specifications with state-specific quadratic trends do not identify lagged effects of MMLs and only report a contemporaneous 0.4% decrease in the likelihood of early term births in the year of the law change (0.001/0.246=0.004). Overall, Table 2.12 does not document any evidence of negative effects of MMLs on infant health outcomes.

In contrast, while results reported in Table 2.13 are sensitive to the inclusion of state-level linear and quadratic trends, they corroborate the concerns for possible negative effects of MMLs on Apgar scores and the associated increased likelihood of severe distress and mild distress births raised in the main analysis. All coefficients on the contemporaneous MML indicator and the MML lags are always negative for the Apgar score outcome and are always positive for the likelihood of severe distress and mild distress births outcomes, although not always statistically significant at the conventional levels. For instance, specifications with state-specific quadratic time trends suggest that MMLs decrease 5-minute Apgar scores by 0.9%

(-0.082/8.903=-0.009) one year after the law goes into effect and by 0.8% (-0.071/8.903=-0.008) five years after the law goes into effect (these coefficients are statistically significant at the 10% level). Severe distress births are estimated to be 25% (0.001/0.004=0.250) more likely one year after the law goes into effect. Mild distress births are estimated to be 40% more likely (0.004/0.010=0.40) one year after the law goes into effect and 30% more likely (0.003/0.010=0.30) two years after the law goes into effect. It is important to note that such large in magnitude negative effects of MMLs on the likelihood of severe distress and mild distress births should be interpreted with caution. The mean values for these outcomes are 0.004 and 0.010, respectively, and the low signal-to-noise ratio in these regressions may be in part responsible for these results.

Overall, I find no evidence to suggest any negative, contemporaneous or lagged, effects of MMLs on birth weight and gestation, however there is an indication of decreased Apgar scores and increased likelihood of severe distress and mild distress births after an MML goes into effect.

2.5.3 Robustness Check: Adding Leads and Lags

The underlying difference-in-differences model used in this chapter relies on the common trends assumption which asserts that that the average change in the control group represents the counterfactual change in the treatment group in the absence of treatment, or that outcomes in treated and untreated groups would have followed common trends had the treatment not occurred. If pre-treatment trends in birth outcomes in MML states were different from those in non-MML states, this assumption would be violated.

In Tables 2.14, 2.15, and 2.16, I present specifications that add 3 years of the policy leads, as well as a contemporaneous policy indicator and 5 years of policy lags to the right side of the estimating equations to test for pre-treatment trends. Estimates in Tables 2.14, 2.15, and 2.16 represent results for birth weight, gestation, and Apgar scores, respectively. In every table, each column represents a result from a separate regression. All specifications include state and year fixed effects, as well as individual- and state-level controls. Columns (1), (4), (7), and (10) do not include trends, columns (2), (5), (8), and (11) contain state-specific linear trends, and columns (3), (6), (9), and (12) add state-specific quadratic trends.

Overall, the results of the robustness check of birth weight and gestation estimates are mixed and specification-dependent. While analysis of specifications with state-specific linear trends in Tables 2.14 and 2.15 supports the common trends assumption for all outcomes except early term births, using specifications with state-specific quadratic trends yields different findings. Controlling for state-specific quadratic trends, I cannot rule out differential trends for birth weight, very low birth weight, low birth weight, gestation, and pre-term births.

On the other hand, robustness checks of the MML effects on Apgar scores are reassuring and provide no evidence that leading up to the effective dates Apgar scores were trending differently in MML and non-MML states.

2.5.4 Subsample Analysis: Teenage Mothers, Adult Mothers with Less Than High School Diploma, and Black Mothers

Effects of MMLs on birth outcomes may display significant heterogeneity by age, race, or other socio-demographic characteristics. For this analysis, I identify three subsamples of interest based on characteristics of women associated with increased likelihood of both poor birth outcomes

and/or marijuana use:[20] 1) teenage mothers (age < 20), 2) mothers with less than high school diploma (age 20+), and 3) black mothers. I hypothesize that if MMLs, in fact, negatively impacted birth outcomes, the estimation results will be most pronounced and convincing for these subsamples.

Tables 2.17, 2.18, and 2.19 report results of the subsample analysis for birth weight, gestation, and Apgar score outcomes, respectively. In each of the three tables, Panel A corresponds to the subsample of teenage mothers, Panel B represents adult mothers with less than high school diploma, and Panel C displays the estimates for the subsample of black mothers. In every table, each column represents a result from a separate regression. All specifications include state and year fixed effects, as well as individual- and state-level controls. Columns (1), (4), (7), and (10) do not include trends, columns (2), (5), (8), and (11) contain state-specific linear trends, and columns (3), (6), (9), and (12) add state-specific quadratic trends.

The findings in Table 2.17 are broadly consistent with the results of the main analysis. For birth weight, I do not find substantial differences in results for the subsamples as compared to the full sample of births. In Table 2.17, the only estimate of β_1 which indicates a negative relationship between MMLs and infant health is that for mothers with less than high school education in the specification with state-specific linear trends (Panel B, column (11)) which indicates that MMLs increase the likelihood of low birth weight births by 2.6% (0.002/0.077=0.026), however it is only significant at the 10% level and is not robust to the exclusion of the trends or the inclusion of state-specific quadratic trends.

Similarly, Table 2.18 does not present strong evidence of any negative effects of MMLs on gestation. Depending on specification, coefficients switch signs, lose or gain significance, and

[20] For more information on the characteristics of reproductive-age women associated with marijuana use, see, for example, Ko et al. (2015) and Brown et al. (2017), for a meta-analysis of the determinants of poor birth outcomes, see, for example, Kramer (1987).

are overall not consistent with the hypothesis that MMLs decrease gestation or increase pre-term, late-term, or early term births.

On the other hand, in Table 2.19, estimates of β_1 are always negative for specifications with Apgar score on the left-hand side of the estimating equation and are always positive for specifications with severe distress and mild distress birth indicators as outcomes (although not always statistically significant and never significant at the 1% level). This is generally consistent with the hypothesis that MMLs decrease Apgar scores. Furthermore, while the magnitude of the effect of MMLs on Apgar scores is very small even when the estimates of β_1 are statistically significant (1.1%–1.3% depending on the subsample in specifications with state-specific linear trends), the effects on the likelihood of severe distress and mild distress births are economically large. For instance, controlling for state-level quadratic trends, I find that the enactment of MMLs is associated with substantial increases in the likelihood of severe distress (22%, 0.002/0.009=0.22) and mild distress births (40%, 0.006/0.015=0.40) for black mothers.

2.6 DISCUSSION AND CONCLUSION

This chapter provides an investigation focused on examining the impact of the state-level MMLs on birth outcomes. Combining data on the entire universe of births in the U.S. between 1990 and 2013 with the effective dates of the state-level MMLs in a difference-in-differences estimation framework, and making use of a rich set of individual-level and state-level characteristics, as well as state-specific time trends, I do not find evidence to support the hypothesis that MMLs have a negative impact on birth weight or gestation, however I find that MMLs are associated with decreases in Apgar scores and increased likelihood of severe distress and mild distress births.

This analysis is not without limitations. This study uses a reduced form approach rather than a structural model. The effects of MMLs on birth outcomes obtained in this chapter should be interpreted as intent-to-treat (ITT) estimates rather than the average treatment effect on the treated (ATET). While there is a significant degree of heterogeneity in MMLs across states,[21] I do not explore it and instead estimate the impact of an "average" MML. Any spillover effects of marijuana liberalization on neighboring states are not captured in this analysis. This chapter does not consider potential longer-run child health outcomes which may plausibly be impacted by MMLs.

Analysis of both direct and indirect effects of MMLs must be considered in policy decisions regarding regulation of marijuana. This study provides new information to the current policy debate surrounding marijuana liberalization legislation.

2.7 REFERENCES

Adams, S., Cotti, C., & Ullman, D. (2017). Seatbelt use as a police avoidance strategy: A test using the legality of medical marijuana. *Safety, 3*(2), 12.

American College of Obstetricians and Gynecologists (ACOG) (2015). Marijuana use during pregnancy and lactation. Committee Opinion No. 637. *Obstetrics & Gynecology, 126*(1), 234-238.

Anderson, D. M., Hansen, B., & Rees, D. I. (2015). Medical marijuana laws and teen marijuana use. *American Law and Economics Review, 17*(2), 495-528.

Anderson, D. M., Hansen, B., & Rees, D. I. (2013). Medical marijuana laws, traffic fatalities, and alcohol consumption. *Journal of Law and Economics, 56*(2), 333-369. doi:10.1086/668812

Anderson, D. M., Rees, D. I., & Sabia, J. J. (2014). Medical marijuana laws and suicides by gender and age. *American Journal of Public Health, 104*(12), 2369-2376.

[21] For a discussion of the differences in state-level MMLs, see, for example: Anderson et al. (2013), Anderson and Rees (2014), Pacula et al. (2015).

Anderson, D. M., & Rees, D. I. (2014). The role of dispensaries: The devil is in the details. *Journal of Policy Analysis and Management, 33*(1), 235-240.

Anderson, D. M., & Rees, D. I. (2014). The legalization of recreational marijuana: How likely is the worst-case scenario? *Journal of Policy Analysis and Management, 33*(1), 221-232. doi: 10.1002/pam.21727

Bertrand, M., Duflo, E., & Mullainathan, S. (2004). How much should we trust differences-in-differences estimates? *The Quarterly Journal of Economics, 119*(1), 249-275.

Bradford, A. C., & Bradford, W. D. (2016). Medical marijuana laws reduce prescription medication use in Medicare part D. *Health Affairs, 35*(7), 1230-1236.

Brown, Q. L., Sarvet, A. L., Shmulewitz, D., Martins, S. S., Wall, M. M., & Hasin, D. S. (2017). Trends in marijuana use among pregnant and nonpregnant reproductive-aged women, 2002-2014. *JAMA, 317*(2), 207-209.

Chabarria, K. C., Racusin, D. A., Antony, K. M., Kahr, M., Suter, M. A., Mastrobattista, J. M., & Aagaard, K. M. (2016). Marijuana use and its effects in pregnancy. *American Journal of Obstetrics and Gynecology, 215*(4), 506-e1.

Chu, Y. W. L. (2015). Do medical marijuana laws increase hard-drug use? *Journal of Law and Economics, 58*(2), 481-517.

Chu, Y. W. L. (2014). The effects of medical marijuana laws on illegal marijuana use. *Journal of Health Economics, 38*, 43-61.

Choi, A., Dave, D., & Sabia, J. J. (2016). Smoke gets in your eyes: Medical marijuana laws and tobacco use. *NBER Working Paper No. 22554*.

Eddy, M. (2010). Medical marijuana: Review and analysis of federal and state policies. Report for Congress No. RL33211. April 2. *Washington, D.C.: Congressional Research Service.*

Gunn, J. K. L., Rosales, C. B., Center, K. E., Nuñez, A., Gibson, S. J., Christ, C., & Ehiri, J. E. (2016). Prenatal exposure to cannabis and maternal and child health outcomes: A systematic review and meta-analysis. *BMJ Open, 6*(4), e009986.

Ko, J. Y., Farr, S. L., Tong, V. T., Creanga, A. A., & Callaghan, W. M. (2015). Prevalence and patterns of marijuana use among pregnant and nonpregnant women of reproductive age. *American Journal of Obstetrics and Gynecology, 213*(2), 201-e1.

Kramer, M. S. (1987). Determinants of low birth weight: Methodological assessment and meta-analysis. *Bulletin of the World Health Organization, 65*(5), 663.

Metz, T. D., & Stickrath, E. H. (2015). Marijuana use in pregnancy and lactation: A review of the evidence. *American Journal of Obstetrics and Gynecology, 213*(6), 761-778.

Nicholas, L. H., & Maclean, J. C. (2016). The impact of medical marijuana laws on the labor supply and health of older adults: Evidence from the health and retirement study. *NBER Working Paper No. 22688*.

O'Keefe, K. (2013). State medical marijuana implementation and federal policy. *Journal of Health Care Law and Policy, 16*(1), 39–58.

Pacula, R. L., Powell, D., Heaton, P., & Sevigny, E. L. (2015). Assessing the effects of medical marijuana laws on marijuana use: The devil is in the details. *Journal of Policy Analysis and Management, 34*(1), 7-31.

Powell, D., Pacula, R. L., & Jacobson, M. (2015). Do medical marijuana laws reduce addictions and deaths related to pain killers? *NBER Working Paper No. 21345.*

Sabia, J. J., & Nguyen, T. T. (2016). The effect of medical marijuana laws on labor market outcomes. *IZA Discussion Paper No. 9831*. Available at SSRN: https://ssrn.com/abstract=2757921.

Sabia, J. J., Swigert, J., and Young, T. (2017). The effect of medical marijuana laws on body weight. *Health Economics, 26*, 6-34, doi: 10.1002/hec.3267.

Ullman, D. F. (2016). The effect of medical marijuana on sickness absence. *Health Economics*, doi: 10.1002/hec.3390.

Volkow, N. D., Compton, W. M., & Wargo, E. M. (2017). The risks of marijuana use during pregnancy. *JAMA, 317*(2), 129-130.

Wen, H., Hockenberry, J. M., & Cummings, J. R. (2015). The effect of medical marijuana laws on adolescent and adult use of marijuana, alcohol, and other substances. *Journal of Health Economics, 42*, 64-80.

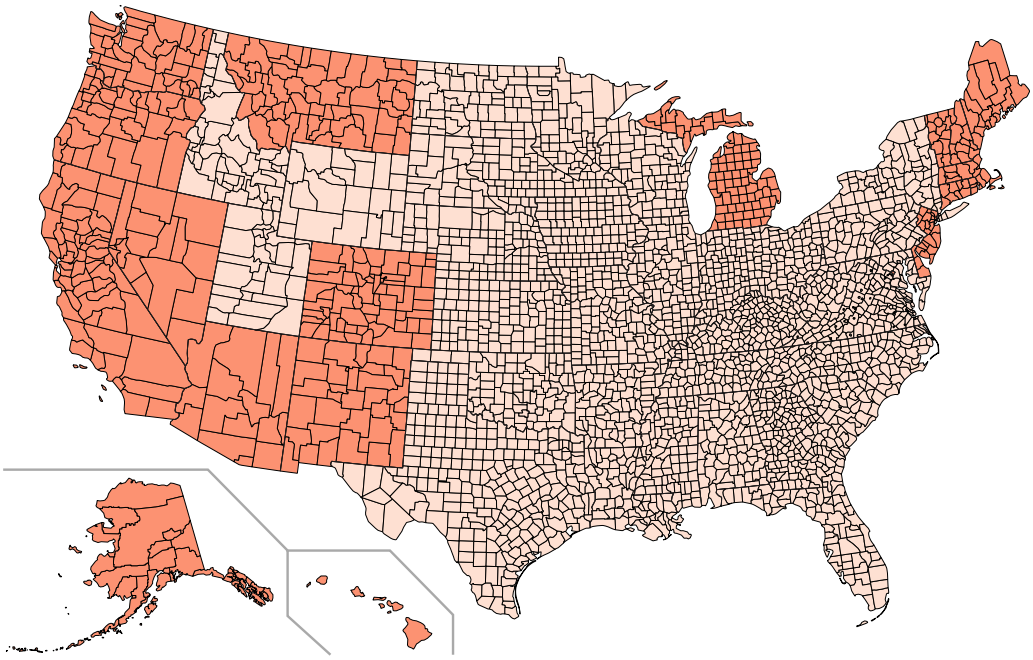


Figure 2.1: State-Level Medical Marijuana Laws Implemented Between 1990 – 2013

Notes: Shaded areas represent states which legalized medical marijuana between years 1990 and 2013.

Table 2.1: Medical Marijuana Laws, 1990–2013

State	Date of Passage of Original Legislation	Effective Date
Alaska	November 3, 1998	March 4, 1999
Arizona	November 2, 2010	April 14, 2011
California	November 5, 1996	November 6, 1996
Colorado	November 7, 2000	June 1, 2001
Connecticut	May 31, 2012	October 1, 2012
Delaware	May 13, 2011	July 1, 2011
District of Columbia	May 4, 2010	July 27, 2010
Hawaii	June 14, 2000	December 28, 2000
Maine	November 2, 1999	December 22, 1999
Massachusetts	November 6, 2012	January 1, 2013
Michigan	November 4, 2008	December 4, 2008
Montana	November 2, 2004	November 2, 2004
Nevada	November 7, 2000	October 1, 2001
New Hampshire	July 23, 2013	July 23, 2013
New Jersey	January 18, 2010	October 1, 2010
New Mexico	April 2, 2007	July 1, 2007
Oregon	November 3, 1998	December 3, 1998
Rhode Island	January 3, 2006	January 3, 2006
Vermont	May 26, 2004	July 1, 2004
Washington	November 3, 1998	November 3, 1998
Total: 19 states and DC		

Notes: These dates for state-level medical marijuana laws are gathered from the National Conference of State Legislatures (accessed at: http://www.ncsl.org/research/health/state-medical-marijuana-laws.aspx), ProCon.org (accessed at: http://medicalmarijuana.procon.org/view.resource.php?resourceID=000881), and the National Organization for the Reform of Marijuana Laws (accessed at: http://norml.org/states). Arkansas, Florida, Illinois, Maryland, Minnesota, New York, North Dakota, Ohio, Pennsylvania, and West Virginia legalized medical marijuana after 2013.

Table 2.2: Sample Breakdown by Year of Birth

Year of Birth	N
1990	4,060,387
1991	4,011,937
1992	3,964,954
1993	3,898,885
1994	3,850,201
1995	3,797,223
1996	3,783,467
1997	3,769,037
1998	3,822,070
1999	3,836,407
2000	3,930,760
2001	3,896,575
2002	3,888,605
2003	3,953,194
2004	3,972,124
2005	3,998,184
2006	4,121,010
2007	4,170,461
2008	4,101,975
2009	3,986,391
2010	3,860,921
2011	3,815,444
2012	3,816,428
2013	3,794,666
Total:	94,101,306

Notes: Underlying data from NCHS. Observations (N) represent maximum sample size.

Table 2.3: Sample Breakdown by State

State	N
Alabama	1,424,544
Alaska	251,419
Arizona	1,957,502
Arkansas	876,343
California	12,712,826
Colorado	1,461,307
Connecticut	983,134
Delaware	256,584
District of Columbia	207,604
Florida	4,842,663
Georgia	2,984,276
Hawaii	434,351
Idaho	484,729
Illinois	4,173,027
Indiana	1,988,593
Iowa	893,179
Kansas	913,088
Kentucky	1,285,031
Louisiana	1,534,795
Maine	327,480
Maryland	1,727,037
Massachusetts	1,835,435
Michigan	3,025,968
Minnesota	1,579,375
Mississippi	985,232
Missouri	1,784,262
Montana	269,710
Nebraska	580,514
Nevada	727,426
New Hampshire	333,522
New Jersey	2,628,339
New Mexico	653,781
New York	6,007,346
North Carolina	2,681,296
North Dakota	200,998
Ohio	3,508,676
Oklahoma	1,174,459
Oregon	1,049,616
Pennsylvania	3,477,182
Rhode Island	293,305
South Carolina	1,314,463
South Dakota	260,009
Tennessee	1,824,710
Texas	8,428,949
Utah	1,090,529
Vermont	155,911
Virginia	2,320,104
Washington	1,917,903
West Virginia	494,019
Wisconsin	1,617,210
Wyoming	161,545
Total:	94,101,306

Notes: Underlying data from NCHS. Observations (N) represent maximum sample size.

Table 2.4: Descriptive Statistics

	Full Sample			MML States			Never-MML States			P-values
	N	Mean	S. D.	N	Mean	S. D.	N	Mean	S. D.	
Outcome variables										
Birth weight (g)	94,028,349	3,329.472	572.744	31,461,140	3,354.837	561.881	62,567,209	3,316.718	577.709	0.000
Extremely low birth weight (<1,000 g)	94,028,349	0.006	0.074	31,461,140	0.005	0.068	62,567,209	0.006	0.077	0.000
Very low birth weight (<1,500 g)	94,028,349	0.011	0.104	31,461,140	0.009	0.097	62,567,209	0.012	0.108	0.000
Low birth weight (<2,500 g)	94,028,349	0.062	0.241	31,461,140	0.055	0.228	62,567,209	0.065	0.247	0.000
Normal birth weight (2,500 to 3,999 g)	94,028,349	0.844	0.363	31,461,140	0.845	0.362	62,567,209	0.844	0.363	0.000
Gestation (weeks)	93,438,700	38.869	2.477	30,966,097	38.973	2.374	62,472,603	38.817	2.525	0.000
Preterm (< 37 weeks)	93,438,700	0.102	0.303	30,966,097	0.092	0.289	62,472,603	0.107	0.310	0.000
Late preterm (34 – 36 weeks)	93,438,700	0.074	0.262	30,966,097	0.068	0.251	62,472,603	0.077	0.266	0.000
Early term (37 – 38 weeks)	93,438,700	0.246	0.431	30,966,097	0.235	0.424	62,472,603	0.252	0.434	0.000
5-minute Apgar score	79,458,604	8.893	0.765	22,174,445	8.881	0.718	57,284,159	8.898	0.782	0.000
Severe distress (Apgar 0 – 3)	79,458,604	0.004	0.067	22,174,445	0.004	0.062	57,284,159	0.005	0.068	0.000
Mild distress (Apgar 4 – 6)	79,458,604	0.010	0.100	22,174,445	0.009	0.009	57,284,159	0.010	0.102	0.000
Individual-level control variables										
Male	94,101,306	0.512	0.500	31,483,123	0.512	0.500	62,618,183	0.512	0.500	0.000
Live birth order	93,624,352	2.044	1.214	31,325,353	2.058	1.228	62,298,999	2.036	1.207	0.000
Age of mother	94,101,306	27.150	6.093	31,483,123	27.690	6.161	62,618,183	26.879	6.040	0.000
Hispanic	93,154,836	0.210	0.407	31,021,635	0.311	0.463	62,133,201	0.159	0.366	0.000
White	94,095,713	0.782	0.413	31,483,123	0.807	0.395	62,618,183	0.769	0.421	0.000
Black	94,095,713	0.156	0.363	31,483,123	0.090	0.287	62,618,183	0.190	0.392	0.000
Native American/Alaskan Native	94,095,713	0.011	0.103	31,483,123	0.017	0.129	62,618,183	0.008	0.087	0.000
Asian/Pacific Islander	94,095,713	0.051	0.220	31,483,123	0.086	0.280	62,618,183	0.033	0.180	0.000
Married	94,101,306	0.646	0.478	31,483,123	0.656	0.475	62,618,183	0.640	0.480	0.000
Education: 8th grade or less	89,076,524	0.059	0.235	29,214,682	0.076	0.265	59,861,842	0.050	0.218	0.000
Education: Some HS	89,076,524	0.158	0.365	29,214,682	0.157	0.364	59,861,842	0.159	0.366	0.000
Education: HS grad	89,076,524	0.312	0.463	29,214,682	0.298	0.457	59,861,842	0.319	0.466	0.000
Education: Some college	89,076,524	0.232	0.422	29,214,682	0.226	0.418	59,861,842	0.235	0.424	0.000
Education: Bachelor's degree	89,076,524	0.152	0.359	29,214,682	0.151	0.358	59,861,842	0.152	0.359	0.000
Education: Masters, doctorate, or professional degree	89,076,524	0.087	0.282	29,214,682	0.093	0.290	59,861,842	0.084	0.359	0.000
State-level control variables										
Marijuana decriminalized	94,101,306	0.341	0.474	31,483,123	0.531	0.499	62,618,183	0.245	0.430	0.000
Recreational marijuana legalized	94,101,306	0.003	0.056	31,483,123	0.009	0.962	62,618,183	0.000	0.000	0.000
Unemployment rate (%)	94,101,306	6.157	1.943	31,483,123	6.726	2.167	62,618,183	5.871	1.752	0.000
Cigarette excise tax (cents/pack)	94,101,306	70.578	67.895	31,483,123	90.030	67.978	62,618,183	60.801	65.714	0.000
Minimum wage	94,101,306	5.559	1.284	31,483,123	5.895	1.445	62,618,183	5.390	1.159	0.000
State EITC	94,101,306	0.253	0.435	31,483,123	0.208	0.406	62,618,183	0.275	0.447	0.000
State refundable EITC	94,101,306	0.233	0.423	31,483,123	0.205	0.404	62,618,183	0.247	0.431	0.000
% of Federal EITC	94,101,306	4.791	9.488	31,483,123	3.721	8.589	62,618,183	5.330	9.866	0.000
Treatment variable										
MML	94,101,306	0.161	0.368	31,483,123	0.483	0.500	62,618,183	0.000	0.000	0.000

Notes: Underlying data from NCHS. Sample means and standard deviations are reported. Observations (N) represent maximum sample size.

Table 2.5: State-Level Difference-in-Differences Estimates of the Effect of Medical Marijuana Laws on Birth Weight Across the Distribution

	Birth weight (g)			Extremely low birth weight (<1,000 g)			Very low birth weight (<1,500 g)			Low birth weight (<2,500 g)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
MML	10.803**	-0.077	2.262	-0.000	0.000	0.000	-0.000	0.000	-0.000	-0.000	0.000	-0.000
	(3.595)	(3.364)	(1.746)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Outcome mean (MML = 0)		3,331.473			0.006			0.011			0.063	
N		1,224			1,224			1,224			1,224	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Each column represents a result from a separate regression. Robust standard errors are clustered at the state level and are in parentheses below OLS coefficients. State-level controls included but not shown: share of male births, average live birth order, average age of mother, average age of mother squared, share of mothers of Hispanic origin, share of Black mothers, share of Native American/Alaskan Native mothers, share of Asian/Pacific Islander mothers, share of married mothers, share of mothers with educational attainment of 8th grade or less, share of mothers with some high school education, share of mothers with some college education, share of mothers with a bachelor's degree, share of mothers with a master's, doctorate, or professional degree, marijuana decriminalization status, recreational marijuana legalization status, unemployment rate, state earned income tax credit program (EITC) status, whether the state EITC is refundable, generosity of the state EITC measured as a percentage of federal credit, minimum wage, and cigarette excise taxes.
Asterisks denote statistical significance as follows: *** p-value ≤ 0.01, ** 0.01 ≤ p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

Table 2.6: State-Level Difference-in-Differences Estimates of the Effect of Medical Marijuana Laws on Gestation Across the Distribution

	Gestation (weeks)			Preterm (<37 weeks)			Late preterm (34 – 36 weeks)			Early term (37 – 38 weeks)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
MML	0.062***	-0.004	-0.010	-0.001	0.001	-0.001	-0.002*	-0.000	-0.001*	-0.014***	-0.001	-0.001
	(0.023)	(0.017)	(0.010)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.004)	(0.003)	(0.003)
Outcome mean (MML = 0)		38.884			0.103			0.074			0.244	
N		1,224			1,224			1,224			1,224	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes

Notes: Each column represents a result from a separate regression. Robust standard errors are clustered at the state level and are in parentheses below OLS coefficients. State-level controls included but not shown: share of male births, average live birth order, average age of mother, average age of mother squared, share of mothers of Hispanic origin, share of Black mothers, share of Native American/Alaskan Native mothers, share of Asian/Pacific Islander mothers, share of married mothers, share of mothers with educational attainment of 8th grade or less, share of mothers with some high school education, share of mothers with some college education, share of mothers with a bachelor's degree, share of mothers with a master's, doctorate, or professional degree, marijuana decriminalization status, recreational marijuana legalization status, unemployment rate, state earned income tax credit program (EITC) status, whether the state EITC is refundable, generosity of the state EITC measured as a percentage of federal credit, minimum wage, and cigarette excise taxes.
Asterisks denote statistical significance as follows: *** p-value ≤ 0.01, ** 0.01 ≤ p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

Table 2.7: State-Level Difference-in-Differences Estimates of the Effect of Medical Marijuana Laws on Apgar Scores Across the Distribution

	5-Minute Apgar Score			Severe Distress (Apgar Score 0 – 3)			Mild Distress (Apgar Score 4 – 6)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
MML	-0.009	-0.004	-0.026	0.000	0.001	0.000	0.002	0.002	0.001
	(0.028)	(0.031)	(0.022)	(0.000)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)
Outcome mean (MML = 0)		8.887			0.005			0.011	
N		1,224			1,224			1,224	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes

Notes: In every panel, each column represents a result from a separate regression. Robust standard errors are clustered at the state level and are in parentheses below OLS coefficients. Individual-level controls included but not shown: sex of infant, dummies for month of birth (February – December; January is the omitted category), dummies for live birth order (1 – 7; 8+ is the omitted category), age of mother, age of mother squared, indicator for Hispanic origin of mother, dummies for race of mother (Black, Native American/Alaskan Native, Asian/Pacific Islander; White is the omitted category), indicator for marital status of mother, dummies for education of mother (8^{th} grade or less; some high school; some college; bachelor's degree; master's, doctorate, or professional degree; high school graduate is the omitted category). State-level controls included but not shown: marijuana decriminalization status, recreational marijuana legalization status, unemployment rate, state earned income tax credit program (EITC) status, whether the state EITC is refundable, generosity of the state EITC measured as a percentage of federal credit, minimum wage, and cigarette excise taxes.
Asterisks denote statistical significance as follows: *** p-value ≤ 0.01, ** 0.01 ≤ p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

Table 2.8: Individual-Level Difference-in-Differences Estimates of the Effect of Medical Marijuana Laws on Birth Weight Across the Distribution

	Birth weight (g)			Extremely low birth weight (<1,000 g)			Very low birth weight (<1,500 g)			Low birth weight (<2,500 g)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: Difference-in-differences, no individual- or state-level controls												
MML	6.142**	2.277	1.103	-0.000	0.000	0.000	-0.000	0.000	0.000	-0.000	0.000	0.000
	(2.963)	(4.679)	(1.608)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)
Outcome mean (MML = 0)		3,326.050			0.006			0.011			0.063	
N		94,028,349			94,028,349			94,028,349			94,028,349	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual-level controls	No	No	No	No	No	No	No	No	No	No	No	No
State-level controls	No	No	No	No	No	No	No	No	No	No	No	No
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes
Panel B: Difference-in-differences, individual-level controls, no state-level controls												
MML	6.190**	4.517	0.860	-0.000	-0.000	-0.000	-0.000	0.000	0.000	-0.000	-0.000	-0.000
	(2.909)	(4.172)	(1.843)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)
Outcome mean (MML = 0)		3,328.076			0.006			0.011			0.063	
N		87,911,694			87,911,694			87,911,694			87,911,694	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level controls	No	No	No	No	No	No	No	No	No	No	No	No
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes
Panel C: Difference-in-differences, individual- and state-level controls												
MML	4.750**	3.721	0.440	-0.000	-0.000	-0.000	-0.000	0.000	0.000	-0.000	-0.000	0.000
	(2.394)	(3.825)	(1.999)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)
Outcome mean (MML = 0)		3,328.076			0.006			0.011			0.063	
N		87,911,694			87,911,694			87,911,694			87,911,694	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes

Notes: In every panel, each column represents a result from a separate regression. Robust standard errors are clustered at the state level and are in parentheses below OLS coefficients. Individual-level controls included but not shown: sex of infant, dummies for month of birth (February – December; January is the omitted category), dummies for live birth order (1 – 7; 8+ is the omitted category), age of mother, age of mother squared, indicator for Hispanic origin of mother, dummies for race of mother (Black, Native American/Alaskan Native, Asian/Pacific Islander; White is the omitted category), indicator for marital status of mother, dummies for education of mother (8^{th} grade or less; some high school; some college; bachelor's degree; master's, doctorate, or professional degree; high school graduate is the omitted category). State-level controls included but not shown: marijuana decriminalization status, recreational marijuana legalization status, unemployment rate, state earned income tax credit program (EITC) status, whether the state EITC is refundable, generosity of the state EITC measured as a percentage of federal credit, minimum wage, and cigarette excise taxes.
Asterisks denote statistical significance as follows: *** p-value ≤ 0.01, ** 0.01 ≤ p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

Table 2.9: Individual-Level Difference-in-Differences Estimates of the Effect of Medical Marijuana Laws on Gestation Across the Distribution

	Gestation (weeks)			Preterm (<37 weeks)			Late preterm (34 – 36 weeks)			Early term (37 – 38 weeks)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: Difference-in-differences, no individual- or state-level controls												
MML	0.048**	0.020	-0.003	-0.003	0.001	0.001	-0.003*	0.000	0.000	-0.012***	-0.006*	-0.001
	(0.019)	(0.022)	(0.007)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)	(0.000)	(0.003)	(0.003)	(0.002)
Outcome mean (MML = 0)		38.862			0.105			0.075			0.246	
N		93,438,700			93,438,700			93,438,700			93,438,700	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual-level controls	No	No	No	No	No	No	No	No	No	No	No	No
State-level controls	No	No	No	No	No	No	No	No	No	No	No	No
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes
Panel B: Difference-in-differences, individual-level controls, no state-level controls												
MML	0.050**	0.027	-0.005	-0.003	0.001	0.001	-0.003*	-0.000	0.000	-0.013***	-0.007*	-0.000
	(0.019)	(0.022)	(0.005)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)	(0.000)	(0.003)	(0.004)	(0.001)
Outcome mean (MML = 0)		38.870			0.104			0.075			0.246	
N		87,405,874			87,405,874			87,405,874			87,405,874	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level controls	No	No	No	No	No	No	No	No	No	No	No	No
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes
Panel C: Difference-in-differences, individual- and state-level controls												
MML	0.049***	0.026*	-0.007	-0.003**	0.001	0.001	-0.004***	-0.000	0.000	-0.009***	-0.006**	-0.000
	(0.014)	(0.015)	(0.005)	(0.002)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.002)	(0.003)	(0.001)
Outcome mean (MML = 0)		38.870			0.104			0.075			0.246	
N		87,405,874			87,405,874			87,405,874			87,405,874	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes

Notes: In every panel, each column represents a result from a separate regression. Robust standard errors are clustered at the state level and are in parentheses below OLS coefficients. Individual-level controls included but not shown: sex of infant, dummies for month of birth (February – December; January is the omitted category), dummies for live birth order (1 – 7; 8+ is the omitted category), age of mother, age of mother squared, indicator for Hispanic origin of mother, dummies for race of mother (Black, Native American/Alaskan Native, Asian/Pacific Islander; White is the omitted category), indicator for marital status of mother, dummies for education of mother (8^{th} grade or less; some high school; some college; bachelor's degree; master's, doctorate, or professional degree; high school graduate is the omitted category). State-level controls included but not shown: marijuana decriminalization status, recreational marijuana legalization status, unemployment rate, state earned income tax credit program (EITC) status, whether the state EITC is refundable, generosity of the state EITC measured as a percentage of federal credit, minimum wage, and cigarette excise taxes.
Asterisks denote statistical significance as follows: *** p-value ≤ 0.01, ** 0.01 ≤ p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

Table 2.10: Individual-Level Difference-in-Differences Estimates of the Effect of Medical Marijuana Laws on Apgar Scores Across the Distribution

	5-Minute Apgar Score			Severe Distress (Apgar Score 0 – 3)			Mild Distress (Apgar Score 4 – 6)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Difference-in-differences, no individual- or state-level controls									
MML	-0.024	-0.047	-0.052	0.001	0.001	0.001	0.002*	0.002	0.003*
	(0.033)	(0.041)	(0.033)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Outcome mean (MML = 0)		8.902			0.004			0.010	
N		79,458,604			79,458,604			79,458,604	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual-level controls	No	No	No	No	No	No	No	No	No
State-level controls	No	No	No	No	No	No	No	No	No
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes
Panel B: Difference-in-differences, individual-level controls, no state-level controls									
MML	-0.050	-0.079*	-0.061	0.001**	0.001*	0.001	0.004***	0.004**	0.003
	(0.034)	(0.045)	(0.042)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Outcome mean (MML = 0)		8.903			0.004			0.010	
N		73,725,046			73,725,046			73,725,046	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level controls	No	No	No	No	No	No	No	No	No
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes
Panel C: Difference-in-differences, individual- and state-level controls									
MML	-0.062**	-0.078*	-0.059	0.001***	0.001*	0.001	0.004***	0.004**	0.003
	(0.030)	(0.037)	(0.043)	(0.000)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Outcome mean (MML = 0)		8.903			0.004			0.010	
N		73,725,046			73,725,046			73,725,046	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes

Notes: In every panel, each column represents a result from a separate regression. Robust standard errors are clustered at the state level and are in parentheses below OLS coefficients. Individual-level controls included but not shown: sex of infant, dummies for month of birth (February – December; January is the omitted category), dummies for live birth order (1 – 7; 8+ is the omitted category), age of mother, age of mother squared, indicator for Hispanic origin of mother, dummies for race of mother (Black, Native American/Alaskan Native, Asian/Pacific Islander; White is the omitted category), indicator for marital status of mother, dummies for education of mother (8^{th} grade or less; some high school; some college; bachelor's degree; master's, doctorate, or professional degree; high school graduate is the omitted category). State-level controls included but not shown: marijuana decriminalization status, recreational marijuana legalization status, unemployment rate, state earned income tax credit program (EITC) status, whether the state EITC is refundable, generosity of the state EITC measured as a percentage of federal credit, minimum wage, and cigarette excise taxes. Asterisks denote statistical significance as follows: *** p-value ≤ 0.01, ** 0.01 ≤ p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

Table 2.11: Lagged Effects of Medical Marijuana Laws on Birth Weight Across the Distribution

	Birth weight (g)			Extremely low birth weight (<1,000 g)			Very low birth weight (<1,500 g)			Low birth weight (<2,500 g)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Year of law change	2.435	0.703	-1.519	-0.000	-0.000	-0.000	0.000	0.000	0.000	-0.000	0.000	0.000
	(1.980)	(2.967)	(1.948)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)
1 year after MML	5.928***	3.890	1.670	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.001	-0.000	-0.000
	(1.999)	(3.177)	(1.884)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
2 years after MML	7.607***	4.890	2.930	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.001	-0.000	-0.000
	(2.213)	(4.536)	(2.895)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
3 years after MML	8.417***	6.881	5.696	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.001	-0.000	-0.001
	(2.374)	(6.225)	(3.725)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
4 years after MML	6.485**	5.451	4.233	0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.000	-0.000
	(2.511)	(6.537)	(3.436)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
5+ years after MML	3.322	4.482	4.992	0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.001
	(3.499)	(7.241)	(3.794)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
Outcome mean (MML = 0)		3,328.076			0.006			0.011			0.063	
N		87,911,694			87,911,694			87,911,694			87,911,694	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes

Notes: In every panel, each column represents a result from a separate regression. Robust standard errors are clustered at the state level and are in parentheses below OLS coefficients. Individual-level controls included but not shown: sex of infant, dummies for month of birth (February – December; January is the omitted category), dummies for live birth order (1 – 7; 8+ is the omitted category), age of mother, age of mother squared, indicator for Hispanic origin of mother, dummies for race of mother (Black, Native American/Alaskan Native, Asian/Pacific Islander; White is the omitted category), indicator for marital status of mother, dummies for education of mother (8^{th} grade or less; some high school; some college; bachelor's degree; master's, doctorate, or professional degree; high school graduate is the omitted category). State-level controls included but not shown: marijuana decriminalization status, recreational marijuana legalization status, unemployment rate, state earned income tax credit program (EITC) status, whether the state EITC is refundable, generosity of the state EITC measured as a percentage of federal credit, minimum wage, and cigarette excise taxes.

Asterisks denote statistical significance as follows: *** p-value ≤ 0.01, ** 0.01 ≤ p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

Table 2.12: Lagged Effects of Medical Marijuana Laws on Gestation Across the Distribution

	Gestation (weeks)			Preterm (<37 weeks)			Late preterm (34 – 36 weeks)			Early term (37 – 38 weeks)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Year of law change	0.028**	0.018	-0.005	0.000	0.001	0.001	0.001	0.000	0.000	-0.009***	-0.006***	-0.001*
	(0.011)	(0.013)	(0.006)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.002)	(0.002)	(0.001)
1 year after MML	0.040***	0.033	0.010	-0.002	0.000	-0.000	-0.002**	-0.000	-0.000	-0.009***	-0.007**	-0.001
	(0.013)	(0.020)	(0.011)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.002)	(0.003)	(0.001)
2 years after MML	0.037**	0.030	0.004	0.001	0.001	0.000	-0.002*	0.000	-0.000	-0.010***	-0.007	-0.001
	(0.014)	(0.022)	(0.012)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.004)	(0.002)
3 years after MML	0.037**	0.040	0.012	-0.002	0.002	0.000	-0.002*	0.000	0.000	-0.008***	-0.007	-0.000
	(0.014)	(0.028)	(0.014)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.006)	(0.003)
4 years after MML	0.048***	0.056	0.030	-0.003*	0.001	-0.001	-0.004***	-0.001	-0.001	-0.009***	-0.009	-0.002
	(0.015)	(0.034)	(0.017)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.007)	(0.004)
5+ years after MML	0.063***	0.093**	0.050	-0.006**	0.000	-0.001	-0.006***	-0.001	-0.001	-0.010***	-0.012	-0.004
	(0.019)	(0.045)	(0.030)	(0.003)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.003)	(0.009)	(0.005)
Outcome mean (MML = 0)		38.870			0.104			0.075			0.246	
N		87,405,874			87,405,874			87,405,874			87,405,874	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes

Notes: In every panel, each column represents a result from a separate regression. Robust standard errors are clustered at the state level and are in parentheses below OLS coefficients. Individual-level controls included but not shown: sex of infant, dummies for month of birth (February – December; January is the omitted category), dummies for live birth order (1 – 7; 8+ is the omitted category), age of mother, age of mother squared, indicator for Hispanic origin of mother, dummies for race of mother (Black, Native American/Alaskan Native, Asian/Pacific Islander; White is the omitted category), indicator for marital status of mother, dummies for education of mother (8^{th} grade or less; some high school; some college; bachelor's degree; master's, doctorate, or professional degree; high school graduate is the omitted category). State-level controls included but not shown: marijuana decriminalization status, recreational marijuana legalization status, unemployment rate, state earned income tax credit program (EITC) status, whether the state EITC is refundable, generosity of the state EITC measured as a percentage of federal credit, minimum wage, and cigarette excise taxes.

Asterisks denote statistical significance as follows: *** p-value ≤ 0.01, ** 0.01 ≤ p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

Table 2.13: Lagged Effects of Medical Marijuana Laws on Apgar Scores Across the Distribution

	5-Minute Apgar Score			Severe Distress (Apgar Score 0 – 3)			Mild Distress (Apgar Score 4 – 6)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Year of law change	-0.052	-0.066	-0.059	0.001	0.001	0.001	0.003*	0.003	0.003
	(0.465)	(0.044)	(0.046)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
1 year after MML	-0.084*	-0.103**	-0.082*	0.001**	0.002**	0.001**	0.005**	0.005**	0.004**
	(0.046)	(0.042)	(0.043)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
2 years after MML	-0.062	-0.084**	-0.058	0.001*	0.001**	0.001	0.004**	0.004**	0.003*
	(0.041)	(0.037)	(0.039)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
3 years after MML	-0.049	-0.073**	-0.035	0.001*	0.001**	0.000	0.003**	0.003*	0.001
	(0.038)	(0.032)	(0.036)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)
4 years after MML	-0.056	-0.086***	-0.033	0.001**	0.001**	0.000	0.004**	0.004***	0.001
	(0.038)	(0.030)	(0.036)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.002)
5+ years after MML	-0.064**	-0.148***	-0.071*	0.002***	0.002***	0.001	0.005***	0.006***	0.003
	(0.028)	(0.039)	(0.041)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Outcome mean (MML = 0)		8.903			0.004			0.010	
N		73,725,046			73,725,046			73,725,046	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes

Notes: In every panel, each column represents a result from a separate regression. Robust standard errors are clustered at the state level and are in parentheses below OLS coefficients. Individual-level controls included but not shown: sex of infant, dummies for month of birth (February – December; January is the omitted category), dummies for live birth order (1 – 7; 8+ is the omitted category), age of mother, age of mother squared, indicator for Hispanic origin of mother, dummies for race of mother (Black, Native American/Alaskan Native, Asian/Pacific Islander; White is the omitted category), indicator for marital status of mother, dummies for education of mother (8^{th} grade or less; some high school; some college; bachelor's degree; master's, doctorate, or professional degree; high school graduate is the omitted category). State-level controls included but not shown: marijuana decriminalization status, recreational marijuana legalization status, unemployment rate, state earned income tax credit program (EITC) status, whether the state EITC is refundable, generosity of the state EITC measured as a percentage of federal credit, minimum wage, and cigarette excise taxes.
Asterisks denote statistical significance as follows: *** p-value ≤ 0.01, ** 0.01 ≤ p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

Table 2.14: Robustness Check: Effect of Medical Marijuana Laws on Birth Weight Across the Distribution, Adding Leads and Lags

	Birth weight (g)			Extremely low birth weight (<1,000 g)			Very low birth weight (<1,500 g)			Low birth weight (<2,500 g)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
3 years before MML	-0.041	-0.910	-3.750***	-0.000	-0.000	-0.000	-0.000	-0.000	0.000	0.001	0.000	0.001*
	(2.771)	(1.700)	(1.361)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
2 years before MML	0.198	-0.407	-5.601**	0.000	0.000**	0.000***	0.000	0.000	0.001***	0.001	0.000	0.001*
	(3.263)	(1.924)	(2.266)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)
1 year before MML	2.454	0.815	-6.556**	-0.000	0.000	0.000*	0.000	0.000	0.001**	0.000	0.000	0.002**
	(2.842)	(3.217)	(2.742)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
Year of law change	2.843	0.660	-7.768**	-0.000	0.000	0.000	0.000	0.000	0.001**	0.000	0.000	0.002**
	(2.880)	(4.090)	(3.241)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
1 year after MML	6.377**	3.865	-5.420	-0.000	-0.000	0.000	-0.000	0.000	0.000*	-0.000	0.000	0.001
	(3.111)	(4.458)	(3.491)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
2 years after MML	8.024***	4.856	-4.906	-0.000	-0.000	0.000	-0.000	0.000	0.000	-0.001	0.000	0.002*
	(3.015)	(5.721)	(4.027)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
3 years after MML	8.827***	6.850	-2.830	-0.000	-0.000	0.000	-0.000	0.000	0.000	-0.001	-0.000	0.001
	(3.192)	(7.386)	(4.736)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
4 years after MML	6.931**	5.436	-4.925	0.000	-0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.002*
	(3.249)	(7.728)	(4.816)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
5+ years after MML	3.731	4.472	-5.448	0.000	-0.000	0.000	0.000	0.000	0.000	-0.000	-0.000	0.002
	(4.331)	(8.608)	(5.397)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
Outcome mean (MML = 0)		3,328.076			0.006			0.011			0.063	
N		87,911,694			87,911,694			87,911,694			87,911,694	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes

Notes: In every panel, each column represents a result from a separate regression. Robust standard errors are clustered at the state level and are in parentheses below OLS coefficients. Individual-level controls included but not shown: sex of infant, dummies for month of birth (February – December; January is the omitted category), dummies for live birth order (1 – 7; 8+ is the omitted category), age of mother, age of mother squared, indicator for Hispanic origin of mother, dummies for race of mother (Black, Native American/Alaskan Native, Asian/Pacific Islander; White is the omitted category), indicator for marital status of mother, dummies for education of mother (8^{th} grade or less; some high school; some college; bachelor's degree; master's, doctorate, or professional degree; high school graduate is the omitted category). State-level controls included but not shown: marijuana decriminalization status, recreational marijuana legalization status, unemployment rate, state earned income tax credit program (EITC) status, whether the state EITC is refundable, generosity of the state EITC measured as a percentage of federal credit, minimum wage, and cigarette excise taxes.
Asterisks denote statistical significance as follows: *** p-value ≤ 0.01, ** 0.01 ≤ p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

Table 2.15: Robustness Check: Effect of Medical Marijuana Laws on Gestation Across the Distribution, Adding Leads and Lags

	Gestation (weeks)			Preterm (<37 weeks)			Late preterm (34 – 36 weeks)			Early term (37 – 38 weeks)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
3 years prior to MML	0.005	0.008	0.007	0.001	0.000	0.001	0.000	-0.000	0.000	-0.003	-0.002	0.001
	(0.012)	(0.014)	(0.007)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.003)	(0.002)
2 years prior to MML	0.022	0.015	-0.017*	0.000	0.001	0.002*	-0.001	-0.000	0.000	-0.007**	-0.005**	0.001
	(0.015)	(0.013)	(0.009)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.002)	(0.002)
1 year prior to MML	0.025	0.020	-0.026**	0.001	0.001	0.003***	-0.000	0.000	0.001	-0.009***	-0.007**	0.001
	(0.016)	(0.015)	(0.012)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.003)	(0.002)
Year of law change	0.036**	0.028	-0.026*	0.000	0.002*	0.003**	-0.001	0.000	0.001	-0.012***	-0.010***	-0.001
	(0.016)	(0.020)	(0.013)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.003)	(0.002)
1 year after MML	0.049***	0.044	-0.014	-0.001	0.001	0.002	-0.002**	-0.001	0.000	-0.012***	-0.011**	-0.000
	(0.017)	(0.027)	(0.016)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.004)	(0.003)
2 years after MML	0.046**	0.041	-0.022	-0.001	0.002*	0.003**	-0.002*	-0.000	0.000	-0.013***	-0.011*	0.000
	(0.019)	(0.029)	(0.019)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.005)	(0.004)
3 years after MML	0.045**	0.052	-0.017	-0.002	0.002*	0.003*	-0.002	0.000	0.001	-0.010***	-0.011	0.001
	(0.019)	(0.036)	(0.022)	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.003)	(0.007)	(0.004)
4 years after MML	0.057***	0.069	-0.008	-0.003	0.001	0.002	-0.004*	-0.001	-0.000	-0.012***	-0.013	-0.001
	(0.189)	(0.042)	(0.023)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.003)	(0.008)	(0.004)
5+ years after MML	0.071***	0.108**	0.014	-0.006**	0.001	0.002	-0.006***	-0.001	-0.000	-0.012***	-0.017*	-0.003
	(0.023)	(0.054)	(0.035)	(0.003)	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.004)	(0.010)	(0.005)
Outcome mean (MML = 0)		38.870			0.104			0.075			0.246	
N		87,405,874			87,405,874			87,405,874			87,405,874	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes

Notes: In every panel, each column represents a result from a separate regression. Robust standard errors are clustered at the state level and are in parentheses below OLS coefficients. Individual-level controls included but not shown: sex of infant, dummies for month of birth (February – December; January is the omitted category), dummies for live birth order (1 – 7; 8+ is the omitted category), age of mother, age of mother squared, indicator for Hispanic origin of mother, dummies for race of mother (Black, Native American/Alaskan Native, Asian/Pacific Islander; White is the omitted category), indicator for marital status of mother, dummies for education of mother (8^{th} grade or less; some high school; some college; bachelor's degree; master's, doctorate, or professional degree; high school graduate is the omitted category). State-level controls included but not shown: marijuana decriminalization status, recreational marijuana legalization status, unemployment rate, state earned income tax credit program (EITC) status, whether the state EITC is refundable, generosity of the state EITC measured as a percentage of federal credit, minimum wage, and cigarette excise taxes.

Asterisks denote statistical significance as follows: *** p-value ≤ 0.01, ** 0.01 ≤ p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

Table 2.16: Robustness Check: Effect of Medical Marijuana Laws on Apgar Scores Across the Distribution, Adding Leads and Lags

	5-Minute Apgar Score			Severe Distress (Apgar Score 0 – 3)			Mild Distress (Apgar Score 4 – 6)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
3 years before MML	0.024*	0.010	0.010	-0.000*	-0.000	-0.000	-0.000	-0.001	-0.000
	(0.012)	(0.009)	(0.008)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
2 years before MML	0.025*	0.012	0.011	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.013)	(0.013)	(0.011)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
1 year before MML	0.006	-0.011	-0.006	0.000	0.000	0.000	0.001	0.001	0.000
	(0.014)	(0.015)	(0.018)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
Year of law change	-0.045	-0.065	-0.055	0.001	0.001	0.001	0.004*	0.003	0.003
	(0.046)	(0.045)	(0.049)	(0.000)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
1 year after MML	-0.077	-0.101**	-0.078*	0.001**	0.002**	0.001*	0.005**	0.005**	0.004*
	(0.047)	(0.044)	(0.043)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
2 years after MML	-0.055	-0.083**	-0.053	0.001*	0.001*	0.001	0.004**	0.004**	0.003
	(0.042)	(0.039)	(0.040)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
3 years after MML	-0.043	-0.071**	-0.030	0.001*	0.001*	0.000	0.003*	0.003*	0.001
	(0.039)	(0.036)	(0.041)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
4 years after MML	-0.049	-0.084**	-0.027	0.001**	0.001*	0.000	0.004**	0.003**	0.001
	(0.040)	(0.035)	(0.043)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
5+ years after MML	-0.056	-0.145***	-0.065	0.002***	0.002**	0.001	0.005***	0.006***	0.003
	(0.029)	(0.043)	(0.050)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.003)
Outcome mean (MML = 0)		8.903			0.004			0.010	
N		73,725,046			73,725,046			73,725,046	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes

Notes: In every panel, each column represents a result from a separate regression. Robust standard errors are clustered at the state level and are in parentheses below OLS coefficients. Individual-level controls included but not shown: sex of infant, dummies for month of birth (February – December; January is the omitted category), dummies for live birth order (1 – 7; 8+ is the omitted category), age of mother, age of mother squared, indicator for Hispanic origin of mother, dummies for race of mother (Black, Native American/Alaskan Native, Asian/Pacific Islander; White is the omitted category), indicator for marital status of mother, dummies for education of mother (8^{th} grade or less; some high school; some college; bachelor's degree; master's, doctorate, or professional degree; high school graduate is the omitted category). State-level controls included but not shown: marijuana decriminalization status, recreational marijuana legalization status, unemployment rate, state earned income tax credit program (EITC) status, whether the state EITC is refundable, generosity of the state EITC measured as a percentage of federal credit, minimum wage, and cigarette excise taxes.
Asterisks denote statistical significance as follows: *** p-value ≤ 0.01, ** 0.01 ≤ p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

Table 2.17: Subsample Analysis of the Effect of Medical Marijuana Laws on Birth Weight Across the Distribution

	Birth weight (g)			Extremely low birth weight (<1,000 g)			Very low birth weight (<1,500 g)			Low birth weight (<2,500 g)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: Teenage mothers (Age < 20)												
MML	6.621**	7.691	2.666	-0.000	-0.000	-0.000	-0.000	-0.000	-0.001*	-0.001	-0.001	-0.001
	(2.658)	(4.999)	(3.652)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.002)
Outcome mean (MML = 0)		3,190.452			0.008			0.016			0.089	
N		9,973,650			9,973,650			9,973,650			9,973,650	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes
Panel B: Mothers with less than high school diploma (Age 20+)												
MML	-3.675	2.371	5.084*	0.000	-0.000	-0.000	0.000	0.000	-0.000	0.001	0.002*	0.000
	(3.476)	(4.087)	(2.887)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
Outcome mean (MML = 0)		3,265.586			0.006			0.012			0.077	
N		13,032,825			13,032,825			13,032,825			13,032,825	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes
Panel C: Black mothers												
MML	21.321***	0.410	-5.076	-0.001	-0.000	-0.000	-0.002	-0.000	-0.000	-0.007***	0.000	0.002
	(5.463)	(8.654)	(4.790)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.002)	(0.003)	(0.002)
Outcome mean (MML = 0)		3,126.878			0.014			0.025			0.114	
N		13,632,011			13,632,011			13,632,011			13,632,011	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes

Notes: In every panel, each column represents a result from a separate regression. Robust standard errors are clustered at the state level and are in parentheses below OLS coefficients. Individual-level controls included but not shown: sex of infant, dummies for month of birth (February – December; January is the omitted category), dummies for live birth order (1 – 7; 8+ is the omitted category), age of mother, age of mother squared, indicator for Hispanic origin of mother, dummies for race of mother (Black, Native American/Alaskan Native, Asian/Pacific Islander; White is the omitted category), indicator for marital status of mother, dummies for education of mother (8^{th} grade or less; some high school; some college; bachelor's degree; master's, doctorate, or professional degree; high school graduate is the omitted category). State-level controls included but not shown: marijuana decriminalization status, recreational marijuana legalization status, unemployment rate, state earned income tax credit program (EITC) status, whether the state EITC is refundable, generosity of the state EITC measured as a percentage of federal credit, minimum wage, and cigarette excise taxes.
Asterisks denote statistical significance as follows: *** p-value ≤ 0.01, ** 0.01 ≤ p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

Table 2.18: Subsample Analysis of the Effect of Medical Marijuana Laws on Gestation Across the Distribution

	Gestation (weeks)			Preterm (<37 weeks)			Late preterm (34 – 36 weeks)			Early term (37 – 38 weeks)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Panel A: Teenage mothers (Age < 20)												
MML	0.022	0.009	0.002	-0.001	0.004***	0.001	-0.002	0.002***	0.000	-0.007***	-0.005**	0.000
	(0.014)	(0.012)	(0.009)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.003)	(0.001)
Outcome mean (MML = 0)		38.779			0.136			0.092			0.225	
N		9,898,205			9,898,205			9,898,205			9,898,205	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes
Panel B: Mothers with less than high school diploma (Age 20+)												
MML	0.019	0.017	-0.001	-0.003	0.004***	0.000	-0.004***	0.001	-0.000	-0.002	-0.007***	-0.001
	(0.018)	(0.013)	(0.008)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)
Outcome mean (MML = 0)		38.803			0.125			0.088			0.243	
N		12,895,286			12,895,286			12,895,286			12,895,286	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes
Panel C: Black mothers												
MML	0.029	-0.001	-0.030**	-0.002	0.005***	0.003**	-0.002	0.002**	0.001	-0.008***	-0.001	0.004
	(0.018)	(0.021)	(0.012)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.003)	(0.005)	(0.003)
Outcome mean (MML = 0)		38.354			0.162			0.105			0.261	
N		13,576,850			13,576,850			13,576,850			13,576,850	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes

Notes: In every panel, each column represents a result from a separate regression. Robust standard errors are clustered at the state level and are in parentheses below OLS coefficients. Individual-level controls included but not shown: sex of infant, dummies for month of birth (February – December; January is the omitted category), dummies for live birth order (1 – 7; 8+ is the omitted category), age of mother, age of mother squared, indicator for Hispanic origin of mother, dummies for race of mother (Black, Native American/Alaskan Native, Asian/Pacific Islander; White is the omitted category), indicator for marital status of mother, dummies for education of mother (8^{th} grade or less; some high school; some college; bachelor's degree; master's, doctorate, or professional degree; high school graduate is the omitted category). State-level controls included but not shown: marijuana decriminalization status, recreational marijuana legalization status, unemployment rate, state earned income tax credit program (EITC) status, whether the state EITC is refundable, generosity of the state EITC measured as a percentage of federal credit, minimum wage, and cigarette excise taxes.
Asterisks denote statistical significance as follows: *** p-value ≤ 0.01, ** 0.01 ≤ p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

Table 2.19: Subsample Analysis of the Effect of Medical Marijuana Laws on Apgar Scores Across the Distribution

	5-Minute Apgar Score			Severe Distress (Apgar Score 0 – 3)			Mild Distress (Apgar Score 4 – 6)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Teenage mothers (Age < 20)									
MML	-0.083**	-0.098**	-0.069	0.002**	0.002*	0.001	0.005***	0.005**	0.004
	(0.036)	(0.043)	(0.052)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.003)
Outcome mean (MML = 0)		8.863			0.006			0.013	
N		8,185,893			8,185,893			8,185,893	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes
Panel B: Mothers with less than high school diploma (Age 20+)									
MML	-0.080**	-0.095*	-0.062	0.002	0.002**	0.001	0.004***	0.004*	0.002
	(0.353)	(0.047)	(0.051)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Outcome mean (MML = 0)		8.897			0.005			0.011	
N		9,597,685			9,597,685			9,597,685	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes
Panel C: Black mothers									
MML	-0.081**	-0.117**	-0.094	0.002*	0.003**	0.002**	0.006***	0.007**	0.006*
	(0.039)	(0.047)	(0.051)	(0.001)	(0.001)	(0.001)	(0.002)	(0.003)	(0.003)
Outcome mean (MML = 0)		8.820			0.009			0.015	
N		12,372,303			12,372,303			12,372,303	
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Individual-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-specific linear trends	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
State-specific quadratic trends	No	No	Yes	No	No	Yes	No	No	Yes

Notes: In every panel, each column represents a result from a separate regression. Robust standard errors are clustered at the state level and are in parentheses below OLS coefficients. Individual-level controls included but not shown: sex of infant, dummies for month of birth (February – December; January is the omitted category), dummies for live birth order (1 – 7; 8+ is the omitted category), age of mother, age of mother squared, indicator for Hispanic origin of mother, dummies for race of mother (Black, Native American/Alaskan Native, Asian/Pacific Islander; White is the omitted category), indicator for marital status of mother, dummies for education of mother (8^{th} grade or less; some high school; some college; bachelor's degree; master's, doctorate, or professional degree; high school graduate is the omitted category). State-level controls included but not shown: marijuana decriminalization status, recreational marijuana legalization status, unemployment rate, state earned income tax credit program (EITC) status, whether the state EITC is refundable, generosity of the state EITC measured as a percentage of federal credit, minimum wage, and cigarette excise taxes.
Asterisks denote statistical significance as follows: *** p-value ≤ 0.01, ** 0.01 ≤ p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

APPENDIX A: CONCEPTUAL FRAMEWORK

Conceptual framework of Chapter 1 follows Rosenzweig and Schultz (1982, 1983).

A family is assumed to derive utility from two types of goods – the health of its children, H, and consumer goods, X. Thus, the utility function of the family is:

$$U = U(H, X).$$

Child health is affected by maternal malaria status during pregnancy M (whether the mother had the disease and how severe it was), purchased or acquired market health inputs Y (such as antenatal care visits), family-specific exogenous health endowment μ (due either to genetic or environmental conditions uninfluenced by parental behavior, but known to the family), and unobserved environmental factor ϵ that can have heterogeneous effects on different individuals. This relationship is described by a health production function:

$$H = F(M, Y, \mu, \epsilon),$$

$$F_M \neq 0, F_Y \neq 0, F_\mu \neq 0, F_\epsilon \neq 0.$$

Maternal malaria status is affected by malaria prevalence MP, malaria preventive measures Z, as well as an unobserved factor ε. This relationship is described by a malaria production function:

$$M = \Gamma(MP, Z, \varepsilon).$$

The family maximizes its utility function given the health production function and the malaria production function, which are assumed to be known, and subject to the budget constraint, given by the following equation:

$$I = XP_X + YP_Y + ZP_Z,$$

where I is income and P_Z, P_Y, P_Z are the prices of the consumption goods, health inputs unrelated to malaria, and malaria preventive measures, respectively.

This model assumes that health cannot be purchased directly. Other goods must be bought or utilized to influence health in a way described by the health production function. Specifically, child investment good Y is purchased only for the purpose of improving child health so that it enters the family utility function only through H. Another important assumption is that the family does not seek to optimize child health, but looks at child health as one utility-augmenting good for which it must sacrifice other goods. Similarly, malaria preventive measures in pregnancy enter neither the utility function nor the child's health production function directly, but only through the maternal malaria production function.

Solving the household optimization problem allows to obtain demand functions for all health inputs (Y and Z) as well as health-neutral goods X:

$$X = D_X(P_X, P_Y, P_Z, I, \mu, \epsilon, \varepsilon) ,$$

$$Y = D_Y(P_X, P_Y, P_Z, I, \mu, \epsilon, \varepsilon) ,$$

$$Z = D_Z(P_X, P_Y, P_Z, I, \mu, \epsilon, \varepsilon) .$$

From the demand functions and the expression $dH = F_M dM + F_Y dY + F_\mu d\mu + F_\epsilon d\epsilon$, one can derive the effects of changes in the prices of the three types of goods on child health. It is easy to see that price effects on child health depend on the effects of changes in prices on the demand for health production inputs as well as on the marginal products of these inputs in the production of health. However, without additional restrictions, the model does not allow to make certain important predictions. Specifically, the model indicates that it is not sufficient to know the price effects of goods in order to predict how changes in prices will affect infant health.

Additionally, it is not clear how the environmental factor ϵ can alter marginal products of inputs or biological processes underlying the health production function. Thus, estimating the parameters of the health production function is necessary for predicting and assessing effects of public policies.

Using the expression for malaria production function, child health production function can be rewritten in the following way:

$$H = \Psi(MP, Z, \varepsilon, Y, \mu, \epsilon).$$

For the purposes of this study, I am most interested in the relationship between malaria preventive measures Z and child health H, $\frac{\partial H}{\partial Z}$. Providing empirical estimation of the relationship between antimalarial efforts and child health has important policy implications. Economic intuition does not provide a clear prediction with respect to the sign of the effect. While those pregnancies which would have ended in a live birth with or without antimalarial interventions, would have benefitted from the campaigns and resulted in healthier children ($\frac{\partial H}{\partial Z} > 0$), the pregnancies that would have ended in a miscarriage in the absence of campaigns, may now have resulted in a live birth, albeit the child health status may have been poor ($\frac{\partial H}{\partial Z} < 0$).

Specifically, Chapter 1 provides an empirical estimation of the following health production function:

$$H_{imr} = \Psi(MP_r, Z_{imr}, \varepsilon_{imr}, Y_{imr}, \mu_{mr}, \epsilon_{imr}),$$

where H_{imr} is birth weight of the child i born to mother m in region r, MP_r is malaria prevalence, Z are health inputs which are bought or allocated only because they affect maternal malaria status, ε is the unobserved environmental factor affecting maternal malaria, Y are consumer goods that can affect birth weight, μ is a family-specific exogenous health endowment due either to genetic or environmental conditions uninfluenced by parental behavior, but known

to the family, and ϵ is the environmental factor that can have heterogeneous effects on different children.

APPENDIX B: ADDITIONAL TABLES AND FIGURES

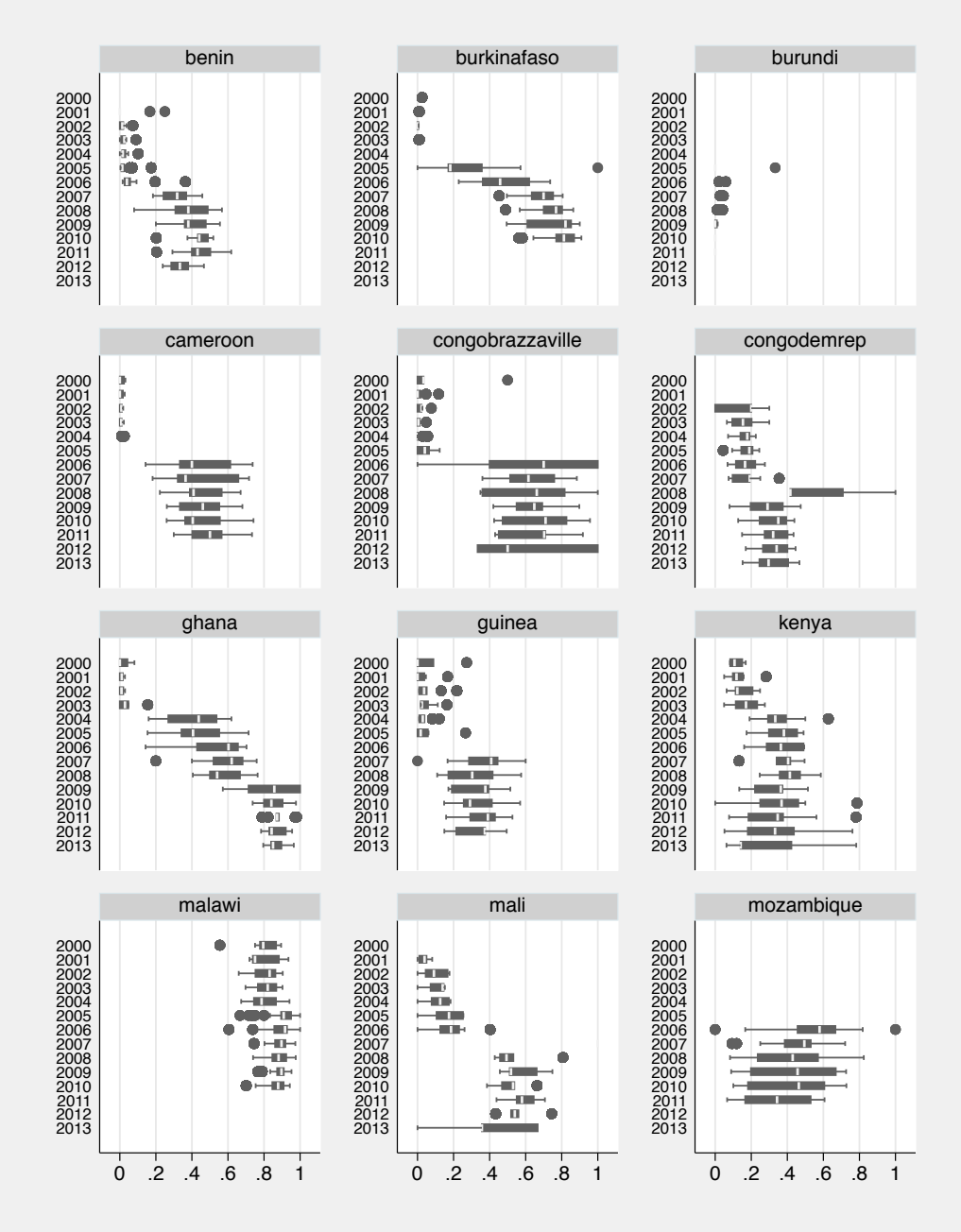


Figure B1: Variation in Region-Level IPTp Coverage Across Countries, 2000–2013

Notes: Underlying data from Demographic and Health Surveys. Region-level IPTp coverage represents proportion of pregnant women reporting receipt of at least one dose of intermittent preventive treatment in pregnancy (IPTp) with sulphadoxine-pyrimethamine.

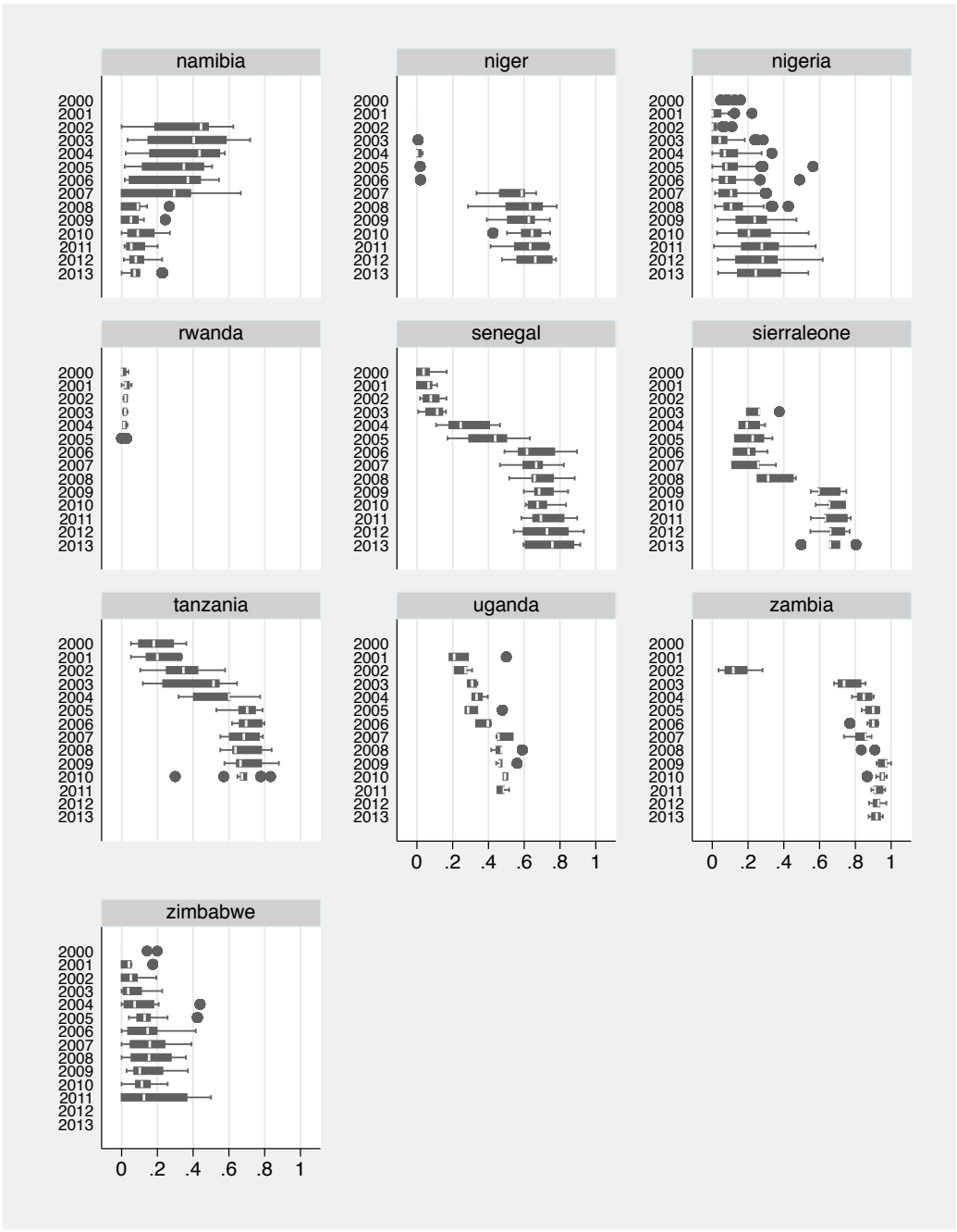


Figure B1: Variation in Region-Level IPTp Coverage Across Countries in Sub-Saharan Africa, 2000–2013 (Continued)

Notes: Underlying data from Demographic and Health Surveys. Region-level IPTp coverage represents proportion of pregnant women reporting receipt of at least one dose of intermittent preventive treatment in pregnancy (IPTp) with sulphadoxine-pyrimethamine.

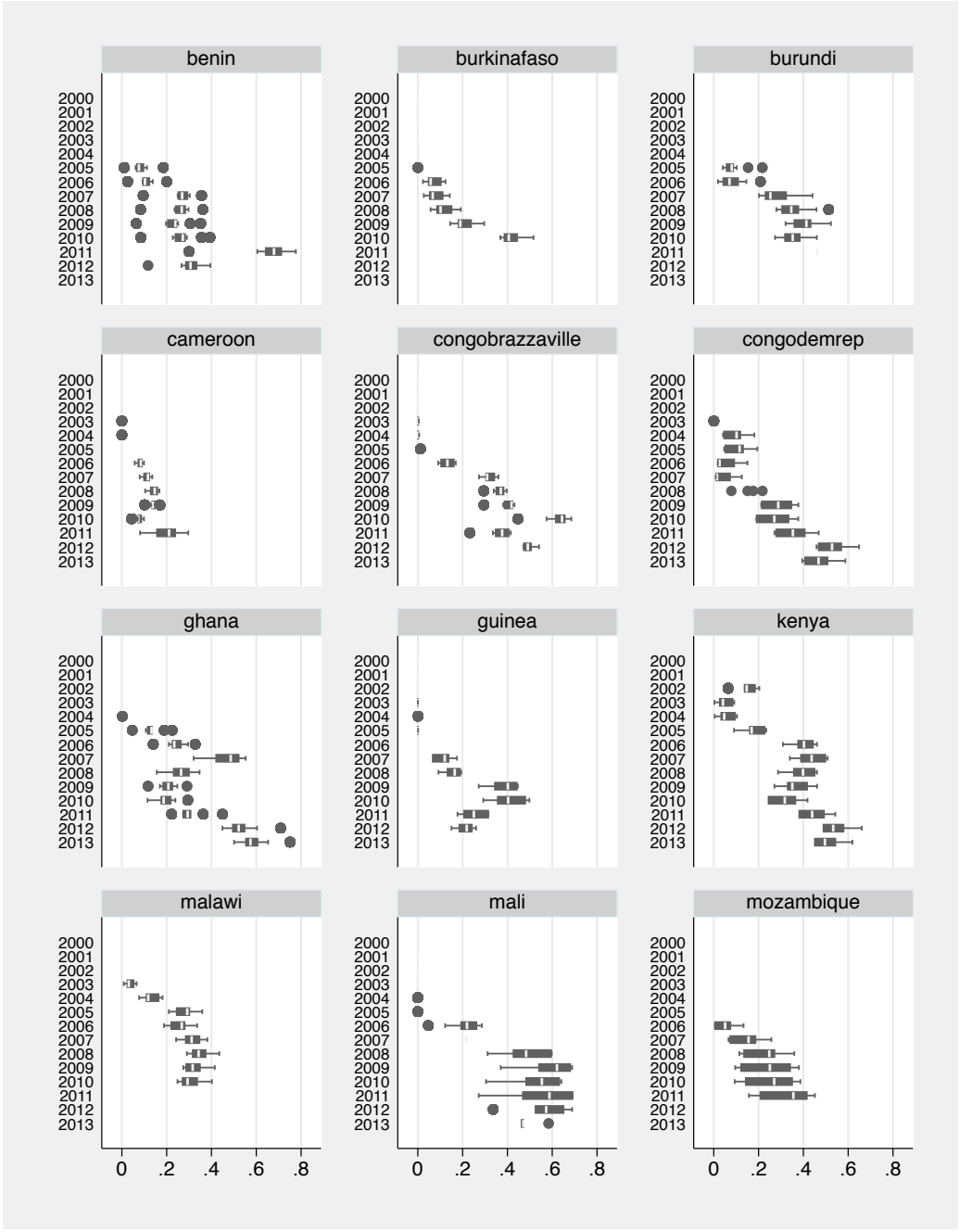


Figure B2: Variation in Region-Level ITN Use Across Countries in Sub-Saharan Africa, 2000–2013

Notes: Underlying data from Malaria Atlas Project. Region level ITN use represents estimated proportion of individuals who slept under an insecticide-treated bed net (ITN) on any given night.

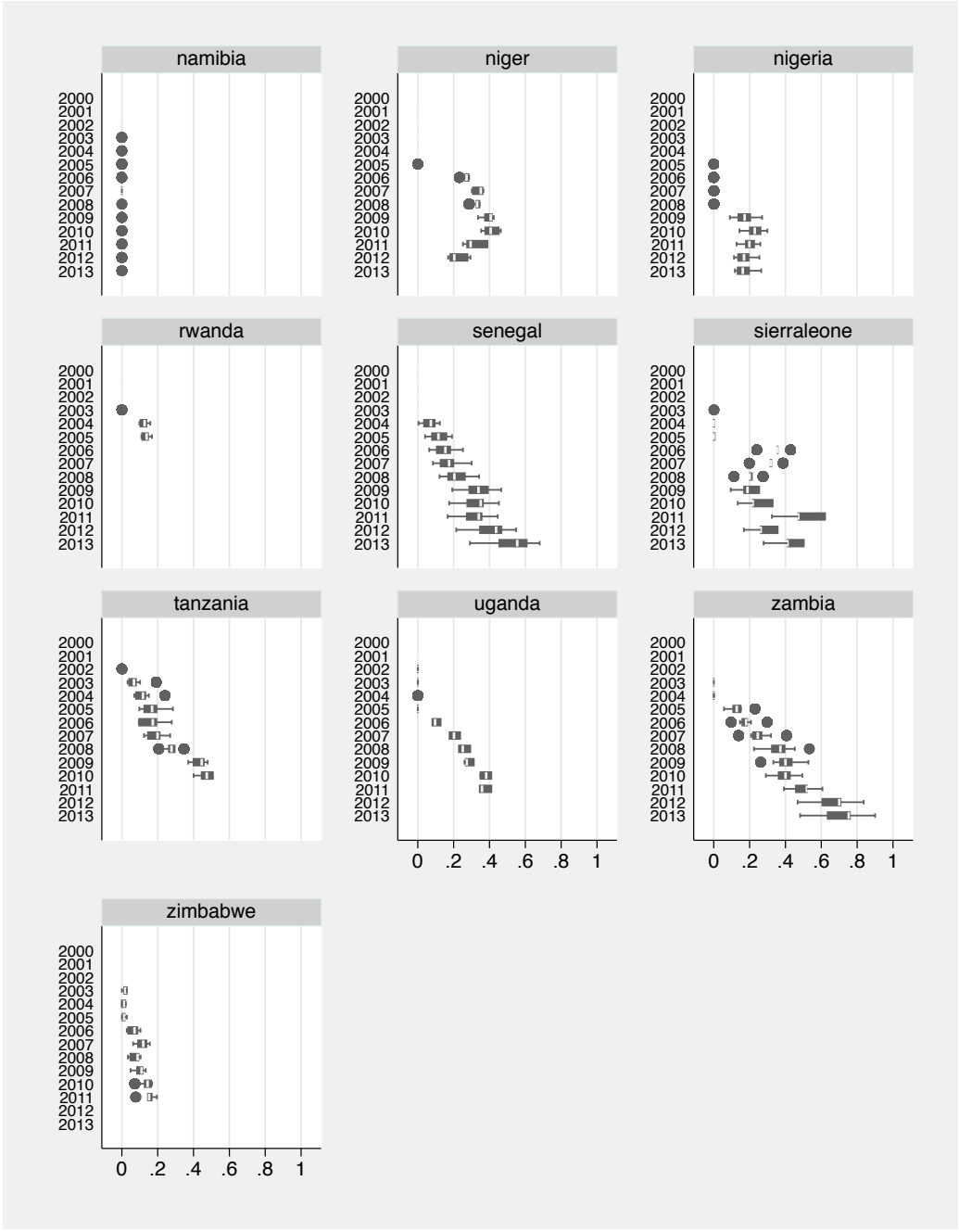


Figure B2: Variation in Region-Level ITN Use Across Countries in Sub-Saharan Africa, 2000–2013 (Continued)

Notes: Underlying data from Malaria Atlas Project. Region level ITN use represents estimated proportion of individuals who slept under an insecticide-treated bed net (ITN) on any given night.

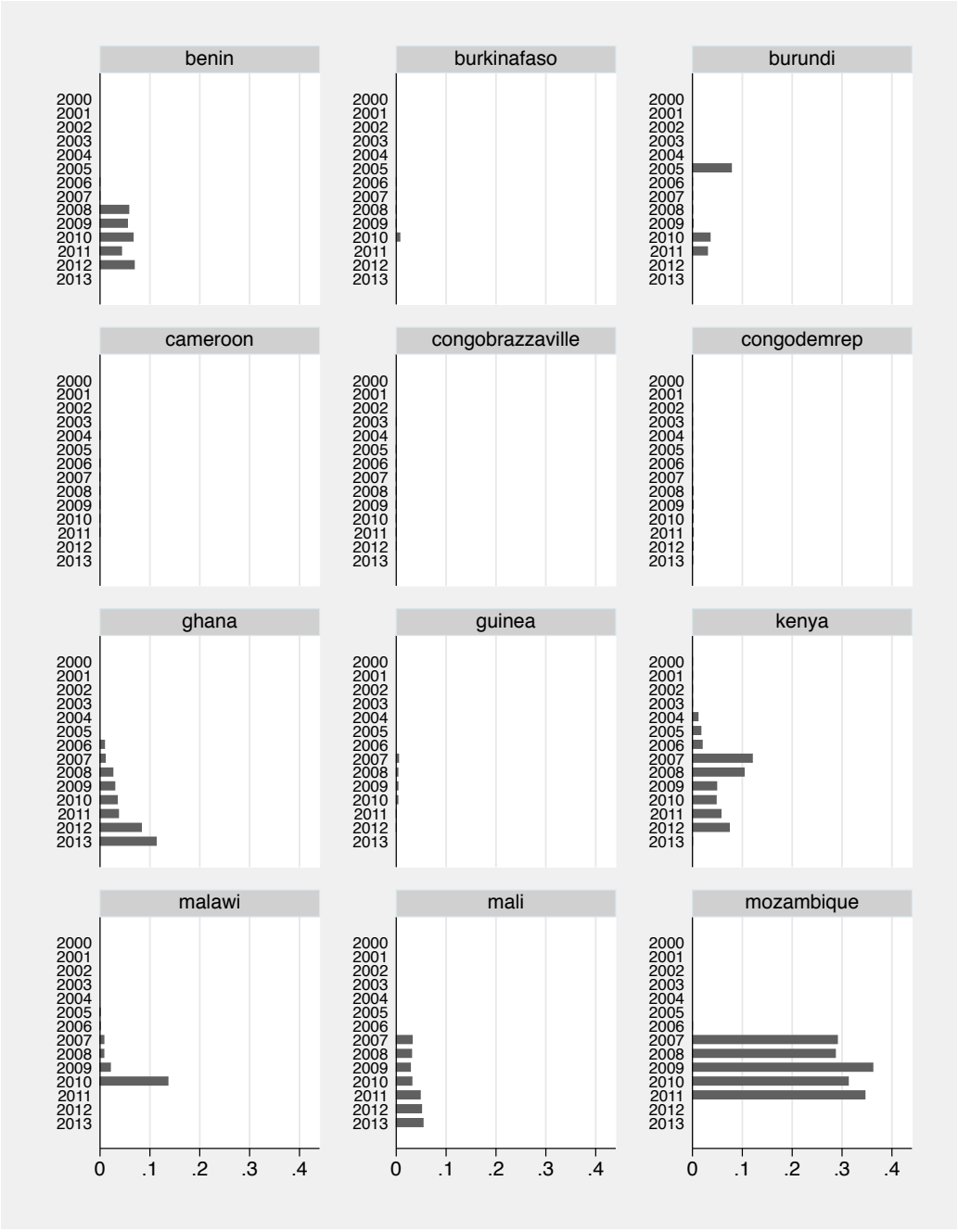


Figure B3: Variation in Country-Level IRS Coverage in Sub-Saharan Africa, 2000–2013

Notes: Underlying data from Malaria Atlas Project. IRS coverage represents estimated proportion of the population protected by indoor residual spraying (IRS) of insecticides.

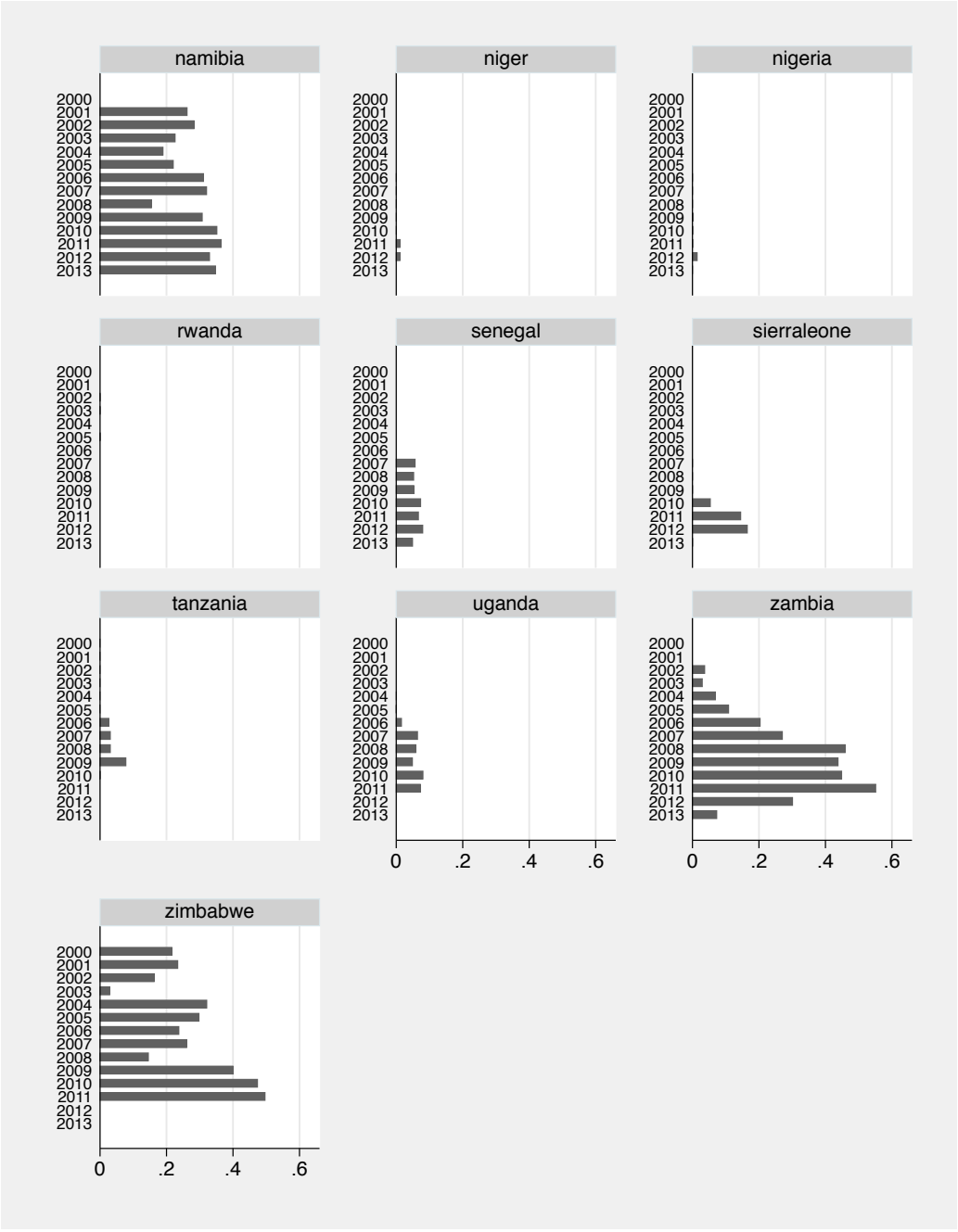


Figure B3: Variation in Country-Level IRS Coverage in Sub-Saharan Africa, 2000–2013 (Continued)

Notes: Underlying data from Malaria Atlas Project. IRS coverage represents estimated proportion of the population protected by indoor residual spraying (IRS) of insecticides.

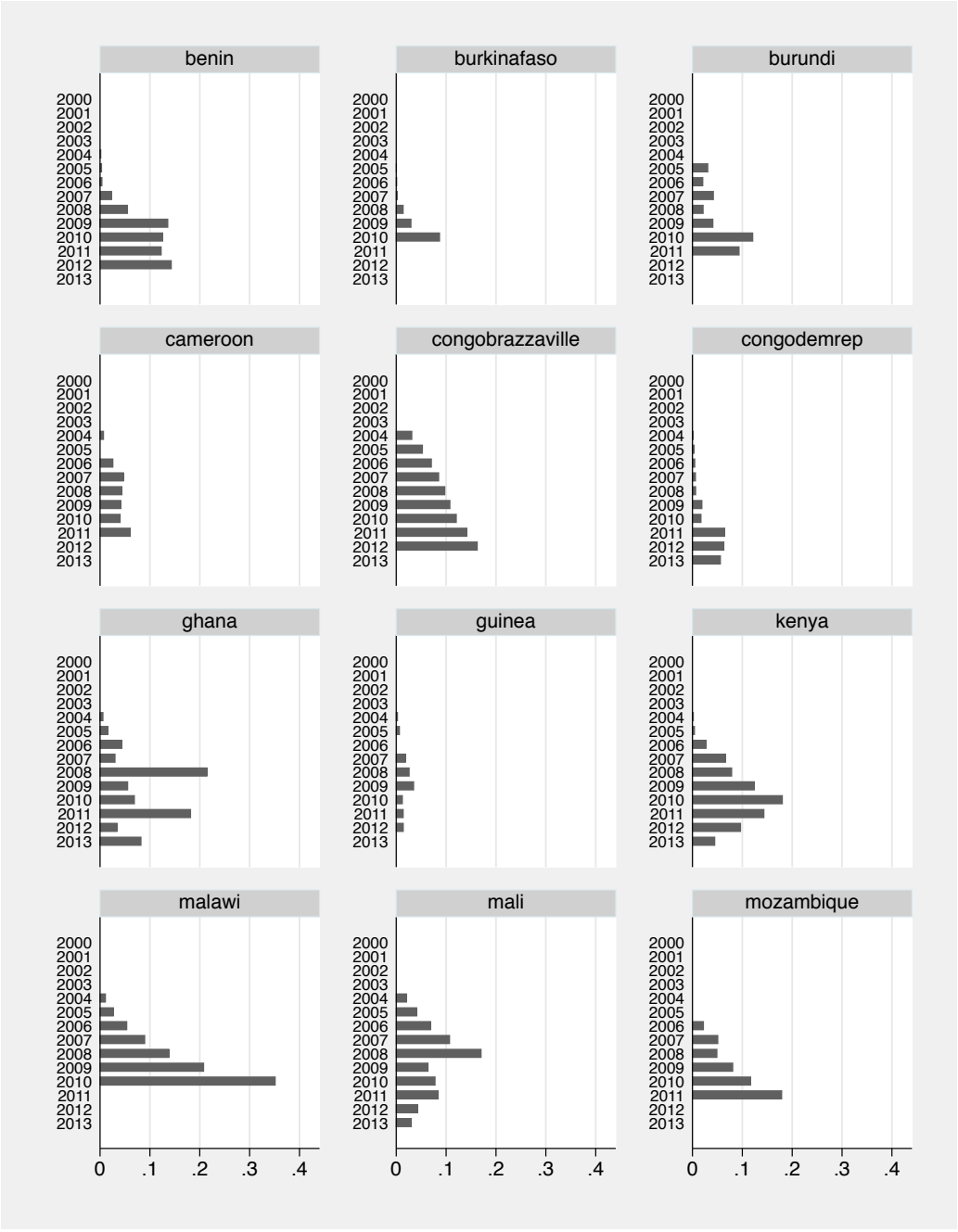


Figure B4: Variation in Country-Level ACT Coverage in Sub-Saharan Africa, 2000–2013

Notes: Underlying data from Malaria Atlas Project. ACT coverage represents estimated proportion of cases of fever in under-5 year olds that were treated with artemisinin-based combination therapy (ACT).

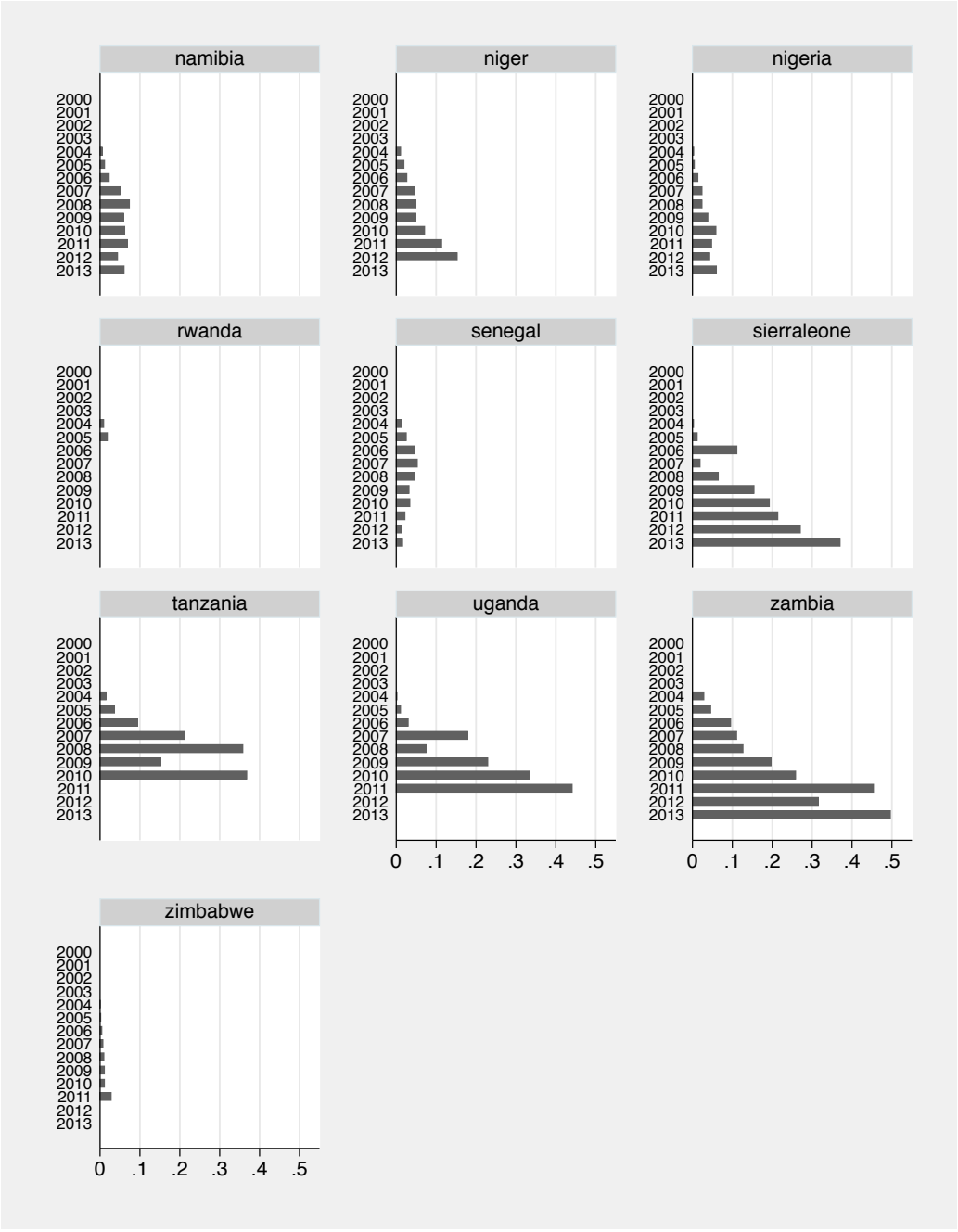


Figure B4: Variation in Country-Level ACT Coverage in Sub-Saharan Africa, 2000–2013 (Continued)

Notes: Underlying data from Malaria Atlas Project. ACT coverage represents estimated proportion of cases of fever in under-5 year olds that were treated with artemisinin-based combination therapy (ACT).

Table B1: Estimated Effects of Antimalarial Interventions on Low Birth Weight Classification Assignment: Model Selection, All Children

VARIABLES	(1) LBW	(2) LBW	(3) LBW	(4) LBW	(5) LBW
Antimalarial interventions variables:					
IPTp-SP	-0.010***	-0.010***	-0.010***	-0.010***	-0.010***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
IPTp-SP x Malaria prevalence	0.006	0.006	0.005	0.001	0.001
	(0.013)	(0.013)	(0.014)	(0.014)	(0.014)
ITN	0.044***	0.044***	0.024	0.012	0.022
	(0.012)	(0.012)	(0.026)	(0.015)	(0.024)
ITN x Malaria prevalence	-0.018	-0.016	-0.011	-0.203**	-0.172
	(0.051)	(0.052)	(0.081)	(0.086)	(0.118)
IRS	-0.002	-0.003	0.013	-0.005	0.002
	(0.018)	(0.019)	(0.043)	(0.016)	(0.044)
IRS x Malaria prevalence	-0.045	-0.057	0.011	0.006	0.068
	(0.099)	(0.099)	(0.112)	(0.109)	(0.108)
ACT	-0.011	-0.008	0.001	0.036	-0.009
	(0.017)	(0.017)	(0.046)	(0.027)	(0.045)
ACT x Malaria prevalence	-0.172*	-0.179*	-0.141	-0.349*	-0.243
	(0.102)	(0.103)	(0.135)	(0.180)	(0.232)
Other variables:					
Household in urban area	0.005**	0.005**	0.005*	0.005**	0.005**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Wealth quintile	-0.006***	-0.006***	-0.006***	-0.006***	-0.006***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Mother has primary education	-0.008***	-0.008***	-0.008***	-0.008***	-0.008***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Mother has at least secondary education	-0.016***	-0.016***	-0.016***	-0.017***	-0.017***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
ANC visits: at most 3	-0.042***	-0.042***	-0.041***	-0.042***	-0.041***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
ANC visits: 4 or more	-0.059***	-0.059***	-0.058***	-0.058***	-0.058***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Mother's age at birth	-0.000**	-0.000**	-0.000**	-0.000**	-0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Male birth	-0.023***	-0.024***	-0.024***	-0.023***	-0.023***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
First birth	0.047***	0.047***	0.048***	0.048***	0.048***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Birth interval under 24 months	0.010***	0.010***	0.011***	0.010***	0.011***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Constant	0.182***	0.183***	0.199***	0.193***	0.182***
	(0.012)	(0.012)	(0.027)	(0.011)	(0.028)
Observations	143,131	143,131	143,131	143,131	143,131
R-squared	0.022	0.024	0.025	0.027	0.029
Region FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Country x Month FE	No	Yes	Yes	Yes	Yes
Country x Year FE	No	No	Yes	No	Yes
Region x Trend	No	No	No	Yes	Yes

Notes: Robust standard errors are clustered at the region level, and are in parentheses below OLS coefficients.
Asterisks denote statistical significance as follows: *** p-value ≤ 0.01, ** 0.01 ≤ p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

Table B2: Estimated Effects of Antimalarial Interventions on Small Size at Birth Classification Assignment: Model Selection, All Children

VARIABLES	(1) Small	(2) Small	(3) Small	(4) Small	(5) Small
Antimalarial interventions variables:					
IPTp-SP	-0.014***	-0.014***	-0.013***	-0.015***	-0.013***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
IPTp-SP x Malaria prevalence	-0.016	-0.017	0.009	-0.002	0.000
	(0.015)	(0.015)	(0.015)	(0.014)	(0.014)
ITN	-0.007	-0.014	-0.033	-0.031	-0.008
	(0.017)	(0.017)	(0.037)	(0.020)	(0.027)
ITN x Malaria prevalence	0.040	0.037	0.289**	0.188*	0.175
	(0.074)	(0.075)	(0.114)	(0.101)	(0.145)
IRS	0.006	0.010	-0.002	0.013	-0.014
	(0.025)	(0.026)	(0.055)	(0.017)	(0.056)
IRS x Malaria prevalence	0.078	0.090	-0.038	0.106	0.069
	(0.091)	(0.093)	(0.152)	(0.090)	(0.144)
ACT	-0.062**	-0.064**	-0.030	-0.057**	-0.030
	(0.029)	(0.029)	(0.046)	(0.028)	(0.046)
ACT x Malaria prevalence	0.015	0.010	-0.070	0.100	-0.189
	(0.172)	(0.173)	(0.167)	(0.188)	(0.228)
Other variables:					
Household in urban area	0.000	0.000	0.001	0.001	0.001
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Wealth quintile	-0.007***	-0.007***	-0.007***	-0.007***	-0.007***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Mother has primary education	-0.014***	-0.015***	-0.015***	-0.014***	-0.014***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Mother has at least secondary education	-0.022***	-0.022***	-0.022***	-0.021***	-0.021***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
ANC visits: at most 3	-0.033***	-0.033***	-0.034***	-0.034***	-0.035***
	(0.005)	(0.005)	(0.005)	(0.004)	(0.004)
ANC visits: 4 or more	-0.054***	-0.054***	-0.055***	-0.055***	-0.056***
	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)
Mother's age at birth	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Male birth	-0.036***	-0.036***	-0.036***	-0.036***	-0.036***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
First birth	0.046***	0.046***	0.046***	0.046***	0.046***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Birth interval under 24 months	0.009***	0.010***	0.010***	0.010***	0.011***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Constant	0.236***	0.232***	0.260***	0.215***	0.218***
	(0.009)	(0.010)	(0.023)	(0.008)	(0.021)
Observations	277,245	277,245	277,245	277,245	277,245
R-squared	0.045	0.045	0.047	0.050	0.052
Region FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Country x Month FE	No	Yes	Yes	Yes	Yes
Country x Year FE	No	No	Yes	No	Yes
Region x Trend	No	No	No	Yes	Yes

Notes: Robust standard errors are clustered at the region level, and are in parentheses below OLS coefficients.
Asterisks denote statistical significance as follows: *** p-value ≤ 0.01, ** 0.01 ≤ p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

Table B3: Estimated Effects of Antimalarial Interventions on Very Small Size at Birth Classification Assignment: Model Selection, All Children

VARIABLES	(1) Very small	(2) Very small	(3) Very small	(4) Very small	(5) Very small
Antimalarial interventions variables:					
IPTp-SP	-0.012***	-0.012***	-0.013***	-0.014***	-0.013***
	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)
IPTp-SP x Malaria prevalence	0.011	0.011	0.034**	0.028**	0.029**
	(0.013)	(0.012)	(0.015)	(0.013)	(0.013)
ITN	0.018*	0.016	-0.017	-0.004	0.022
	(0.011)	(0.011)	(0.016)	(0.010)	(0.016)
ITN x Malaria prevalence	-0.122**	-0.123*	0.072	0.045	0.033
	(0.062)	(0.062)	(0.086)	(0.046)	(0.064)
IRS	0.004	0.005	0.010	0.007	0.014
	(0.014)	(0.014)	(0.022)	(0.007)	(0.020)
IRS x Malaria prevalence	0.011	0.013	-0.139	0.056	0.009
	(0.054)	(0.055)	(0.089)	(0.047)	(0.063)
ACT	-0.040*	-0.040*	-0.001	-0.008	0.003
	(0.023)	(0.023)	(0.020)	(0.018)	(0.020)
ACT x Malaria prevalence	0.030	0.033	-0.047	0.125	0.020
	(0.122)	(0.122)	(0.126)	(0.127)	(0.128)
Household in urban area	-0.001	-0.001	-0.001	-0.001	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Wealth quintile	-0.003***	-0.003***	-0.003***	-0.003***	-0.003***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Mother has primary education	-0.005***	-0.005***	-0.005***	-0.005***	-0.005***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Mother has at least secondary education	-0.006***	-0.006***	-0.006***	-0.006***	-0.006***
	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)
ANC visits: at most 3	-0.020***	-0.020***	-0.019***	-0.018***	-0.019***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
ANC visits: 4 or more	-0.028***	-0.028***	-0.027***	-0.027***	-0.027***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Mother's age at birth	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Male birth	-0.013***	-0.013***	-0.013***	-0.013***	-0.013***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
First birth	0.019***	0.019***	0.019***	0.019***	0.019***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)
Birth interval under 24 months	0.006***	0.006***	0.006***	0.006***	0.006***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Constant	0.087***	0.089***	0.094***	0.075***	0.064***
	(0.006)	(0.006)	(0.010)	(0.005)	(0.008)
Observations	277,245	277,245	277,245	277,245	277,245
R-squared	0.035	0.035	0.038	0.042	0.043
Region FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Country x Month FE	No	Yes	Yes	Yes	Yes
Country x Year FE	No	No	Yes	No	Yes
Region x Trend	No	No	No	Yes	Yes

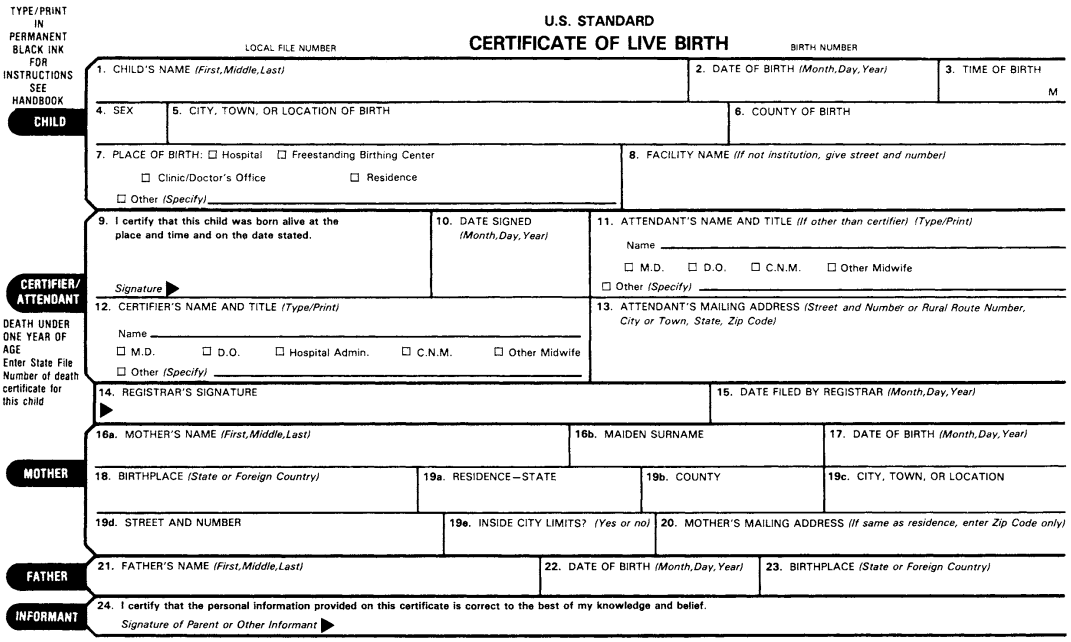
Notes: Robust standard errors are clustered at the region level, and are in parentheses below OLS coefficients.
Asterisks denote statistical significance as follows: *** p-value ≤ 0.01, ** 0.01 ≤ p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

Table B4: Estimated Effects of Antimalarial Interventions on Birth Weight: Model Selection, All Children

VARIABLES	(1) Birth weight	(2) Birth weight	(3) Birth weight	(4) Birth weight	(5) Birth weight
Antimalarial interventions variables:					
IPTp-SP	-1.825	-1.904	-6.394	-0.727	-5.096
	(6.301)	(6.341)	(6.459)	(6.342)	(6.524)
IPTp-SP x Malaria prevalence	-100.697***	-101.784***	-86.504***	-73.607**	-79.315**
	(30.976)	(30.931)	(31.080)	(32.383)	(32.953)
ITN	29.563	29.768	-55.957	126.207***	-115.455*
	(32.089)	(32.644)	(63.517)	(38.049)	(59.914)
ITN x Malaria prevalence	291.969**	293.476**	138.597	347.382*	468.861*
	(137.463)	(136.191)	(223.385)	(197.097)	(267.334)
IRS	-126.370**	-130.582**	189.883**	62.289	191.530*
	(52.036)	(51.476)	(92.477)	(42.350)	(97.422)
IRS x Malaria prevalence	-550.851***	-536.789***	-319.081	-91.926	-320.276
	(196.455)	(195.358)	(264.038)	(214.405)	(264.232)
ACT	-185.051***	-183.811***	-153.459	20.569	-181.241
	(50.387)	(52.264)	(122.405)	(69.489)	(121.337)
ACT x Malaria prevalence	-155.455	-126.439	-237.718	209.338	745.234
	(309.611)	(319.684)	(372.001)	(399.119)	(500.163)
Other variables:					
Household in urban area	-16.568**	-16.299**	-15.563**	-15.837**	-16.100**
	(7.673)	(7.685)	(7.677)	(7.666)	(7.732)
Wealth quintile	6.824***	6.739***	6.240***	6.096***	6.087***
	(2.292)	(2.293)	(2.292)	(2.277)	(2.269)
Mother has primary education	33.665***	33.649***	33.810***	33.985***	33.797***
	(6.369)	(6.302)	(6.396)	(6.358)	(6.407)
Mother has at least secondary education	21.254***	21.469***	21.090***	21.277***	20.653***
	(6.883)	(6.815)	(6.799)	(6.755)	(6.769)
ANC visits: at most 3	21.309	22.502	21.227	21.863	21.463
	(21.723)	(21.759)	(21.684)	(21.048)	(21.263)
ANC visits: 4 or more	82.310***	83.695***	80.940***	83.685***	81.386***
	(22.098)	(22.136)	(22.104)	(21.319)	(21.563)
Mother's age at birth	1.623***	1.605***	1.480***	1.652***	1.483***
	(0.349)	(0.351)	(0.349)	(0.348)	(0.348)
Male birth	115.550***	115.497***	115.512***	115.230***	115.237***
	(3.782)	(3.817)	(3.837)	(3.840)	(3.855)
First birth	-149.499***	-149.754***	-150.430***	-149.734***	-150.520***
	(5.526)	(5.564)	(5.561)	(5.589)	(5.571)
Birth interval under 24 months	-12.872**	-13.329**	-15.137**	-13.565**	-16.132***
	(5.886)	(5.832)	(5.882)	(5.843)	(5.872)
Constant	3,105.719***	3,102.348***	3,158.142***	3,121.799***	3,148.886***
	(34.362)	(34.195)	(53.462)	(29.507)	(56.041)
Observations	143,131	143,131	143,131	143,131	143,131
R-squared	0.071	0.073	0.076	0.078	0.081
Region FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Country x Month FE	No	Yes	Yes	Yes	Yes
Country x Year FE	No	No	Yes	No	Yes
Region x Trend	No	No	No	Yes	Yes

Notes: Robust standard errors are clustered at the region level, and are in parentheses below OLS coefficients.
Asterisks denote statistical significance as follows: *** p-value ≤ 0.01, ** 0.01 ≤ p-value ≤ 0.05, * 0.05 < p-value ≤ 0.10.

APPENDIX C: ADDITIONAL TABLES AND FIGURES



TYPE/PRINT IN PERMANENT BLACK INK FOR INSTRUCTIONS SEE HANDBOOK

U.S. STANDARD

CERTIFICATE OF LIVE BIRTH

LOCAL FILE NUMBER

BIRTH NUMBER

CHILD

1. CHILD'S NAME *(First,Middle,Last)*
2. DATE OF BIRTH *(Month,Day,Year)*
3. TIME OF BIRTH M
4. SEX
5. CITY, TOWN, OR LOCATION OF BIRTH
6. COUNTY OF BIRTH
7. PLACE OF BIRTH: ☐ Hospital ☐ Freestanding Birthing Center ☐ Clinic/Doctor's Office ☐ Residence ☐ Other *(Specify)*
8. FACILITY NAME *(If not institution, give street and number)*

CERTIFIER/ ATTENDANT

9. **I certify that this child was born alive at the place and time and on the date stated.** *Signature* ▶
10. DATE SIGNED *(Month,Day,Year)*
11. ATTENDANT'S NAME AND TITLE *(If other than certifier) (Type/Print)* Name ☐ M.D. ☐ D.O. ☐ C.N.M. ☐ Other Midwife ☐ Other *(Specify)*
12. CERTIFIER'S NAME AND TITLE *(Type/Print)* Name ☐ M.D. ☐ D.O. ☐ Hospital Admin. ☐ C.N.M. ☐ Other Midwife ☐ Other *(Specify)*
13. ATTENDANT'S MAILING ADDRESS *(Street and Number or Rural Route Number, City or Town, State, Zip Code)*

DEATH UNDER ONE YEAR OF AGE Enter State File Number of death certificate for this child

14. REGISTRAR'S SIGNATURE ▶
15. DATE FILED BY REGISTRAR *(Month,Day,Year)*

MOTHER

16a. MOTHER'S NAME *(First,Middle,Last)*
16b. MAIDEN SURNAME
17. DATE OF BIRTH *(Month,Day,Year)*
18. BIRTHPLACE *(State or Foreign Country)*
19a. RESIDENCE—STATE
19b. COUNTY
19c. CITY, TOWN, OR LOCATION
19d. STREET AND NUMBER
19e. INSIDE CITY LIMITS? *(Yes or no)*
20. MOTHER'S MAILING ADDRESS *(If same as residence, enter Zip Code only)*

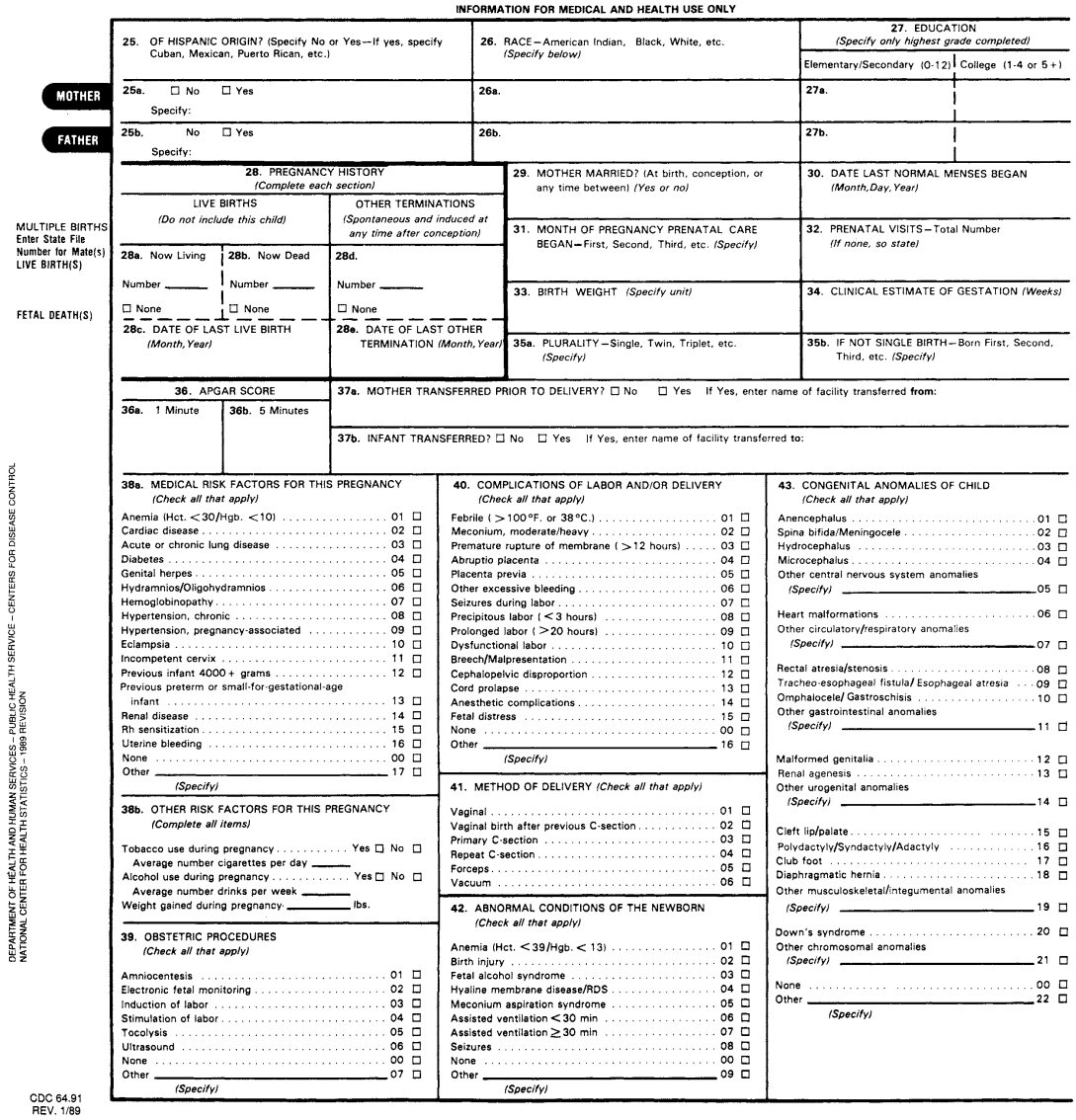
FATHER

21. FATHER'S NAME *(First,Middle,Last)*
22. DATE OF BIRTH *(Month,Day,Year)*
23. BIRTHPLACE *(State or Foreign Country)*

INFORMANT

24. **I certify that the personal information provided on this certificate is correct to the best of my knowledge and belief.** *Signature of Parent or Other Informant* ▶

Figure C1: U.S. Standard Certificate of Live Birth: 1989 Revision



INFORMATION FOR MEDICAL AND HEALTH USE ONLY

25. OF HISPANIC ORIGIN? (Specify No or Yes—If yes, specify Cuban, Mexican, Puerto Rican, etc.)

26. RACE—American Indian, Black, White, etc. (Specify below)

27. EDUCATION (Specify only highest grade completed)
Elementary/Secondary (0-12) | College (1-4 or 5+)

MOTHER
25a. ☐ No ☐ Yes
Specify:
26a.
27a.

FATHER
25b. No ☐ Yes
Specify:
26b.
27b.

28. PREGNANCY HISTORY (Complete each section)

LIVE BIRTHS (Do not include this child)

MULTIPLE BIRTHS Enter State File Number for Mate(s) LIVE BIRTH(S)

28a. Now Living
Number ____
☐ None

28b. Now Dead
Number ____
☐ None

FETAL DEATH(S)

OTHER TERMINATIONS (Spontaneous and induced at any time after conception)

28d.
Number ____
☐ None

28c. DATE OF LAST LIVE BIRTH (Month, Year)

28e. DATE OF LAST OTHER TERMINATION (Month, Year)

29. MOTHER MARRIED? (At birth, conception, or any time between) (Yes or no)

30. DATE LAST NORMAL MENSES BEGAN (Month, Day, Year)

31. MONTH OF PREGNANCY PRENATAL CARE BEGAN—First, Second, Third, etc. (Specify)

32. PRENATAL VISITS—Total Number (If none, so state)

33. BIRTH WEIGHT (Specify unit)

34. CLINICAL ESTIMATE OF GESTATION (Weeks)

35a. PLURALITY—Single, Twin, Triplet, etc. (Specify)

35b. IF NOT SINGLE BIRTH—Born First, Second, Third, etc. (Specify)

36. APGAR SCORE

36a. 1 Minute

36b. 5 Minutes

37a. MOTHER TRANSFERRED PRIOR TO DELIVERY? ☐ No ☐ Yes If Yes, enter name of facility transferred from:

37b. INFANT TRANSFERRED? ☐ No ☐ Yes If Yes, enter name of facility transferred to:

38a. MEDICAL RISK FACTORS FOR THIS PREGNANCY (Check all that apply)

Anemia (Hct. <30/Hgb. <10) ..... 01 ☐
Cardiac disease ..... 02 ☐
Acute or chronic lung disease ..... 03 ☐
Diabetes ..... 04 ☐
Genital herpes ..... 05 ☐
Hydramnios/Oligohydramnios ..... 06 ☐
Hemoglobinopathy ..... 07 ☐
Hypertension, chronic ..... 08 ☐
Hypertension, pregnancy-associated ..... 09 ☐
Eclampsia ..... 10 ☐
Incompetent cervix ..... 11 ☐
Previous infant 4000+ grams ..... 12 ☐
Previous preterm or small-for-gestational-age infant ..... 13 ☐
Renal disease ..... 14 ☐
Rh sensitization ..... 15 ☐
Uterine bleeding ..... 16 ☐
None ..... 00 ☐
Other _____ 17 ☐
(Specify)

38b. OTHER RISK FACTORS FOR THIS PREGNANCY (Complete all items)

Tobacco use during pregnancy ..... Yes ☐ No ☐
Average number cigarettes per day _____
Alcohol use during pregnancy ..... Yes ☐ No ☐
Average number drinks per week _____
Weight gained during pregnancy _____ lbs.

39. OBSTETRIC PROCEDURES (Check all that apply)

Amniocentesis ..... 01 ☐
Electronic fetal monitoring ..... 02 ☐
Induction of labor ..... 03 ☐
Stimulation of labor ..... 04 ☐
Tocolysis ..... 05 ☐
Ultrasound ..... 06 ☐
None ..... 00 ☐
Other _____ 07 ☐
(Specify)

40. COMPLICATIONS OF LABOR AND/OR DELIVERY (Check all that apply)

Febrile (>100°F. or 38°C.) ..... 01 ☐
Meconium, moderate/heavy ..... 02 ☐
Premature rupture of membrane (>12 hours) ..... 03 ☐
Abruptio placenta ..... 04 ☐
Placenta previa ..... 05 ☐
Other excessive bleeding ..... 06 ☐
Seizures during labor ..... 07 ☐
Precipitous labor (<3 hours) ..... 08 ☐
Prolonged labor (>20 hours) ..... 09 ☐
Dysfunctional labor ..... 10 ☐
Breech/Malpresentation ..... 11 ☐
Cephalopelvic disproportion ..... 12 ☐
Cord prolapse ..... 13 ☐
Anesthetic complications ..... 14 ☐
Fetal distress ..... 15 ☐
None ..... 00 ☐
Other _____ 16 ☐
(Specify)

41. METHOD OF DELIVERY (Check all that apply)

Vaginal ..... 01 ☐
Vaginal birth after previous C-section ..... 02 ☐
Primary C-section ..... 03 ☐
Repeat C-section ..... 04 ☐
Forceps ..... 05 ☐
Vacuum ..... 06 ☐

42. ABNORMAL CONDITIONS OF THE NEWBORN (Check all that apply)

Anemia (Hct. <39/Hgb. <13) ..... 01 ☐
Birth injury ..... 02 ☐
Fetal alcohol syndrome ..... 03 ☐
Hyaline membrane disease/RDS ..... 04 ☐
Meconium aspiration syndrome ..... 05 ☐
Assisted ventilation <30 min ..... 06 ☐
Assisted ventilation ≥30 min ..... 07 ☐
Seizures ..... 08 ☐
None ..... 00 ☐
Other _____ 09 ☐
(Specify)

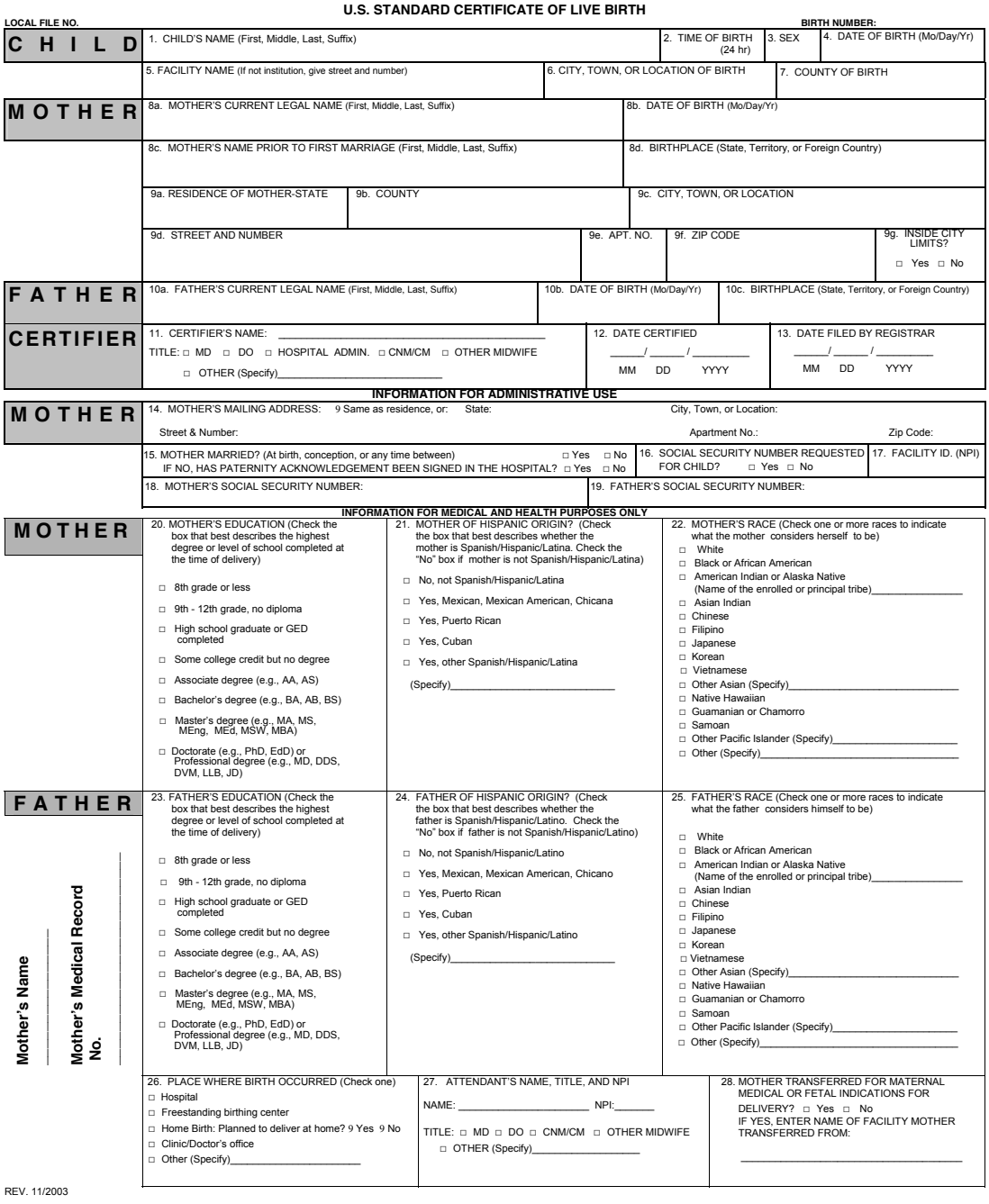
43. CONGENITAL ANOMALIES OF CHILD (Check all that apply)

Anencephalus ..... 01 ☐
Spina bifida/Meningocele ..... 02 ☐
Hydrocephalus ..... 03 ☐
Microcephalus ..... 04 ☐
Other central nervous system anomalies (Specify) _____ 05 ☐
Heart malformations ..... 06 ☐
Other circulatory/respiratory anomalies (Specify) _____ 07 ☐
Rectal atresia/stenosis ..... 08 ☐
Tracheo-esophageal fistula/ Esophageal atresia ..... 09 ☐
Omphalocele/ Gastroschisis ..... 10 ☐
Other gastrointestinal anomalies (Specify) _____ 11 ☐
Malformed genitalia ..... 12 ☐
Renal agenesis ..... 13 ☐
Other urogenital anomalies (Specify) _____ 14 ☐
Cleft lip/palate ..... 15 ☐
Polydactyly/Syndactyly/Adactyly ..... 16 ☐
Club foot ..... 17 ☐
Diaphragmatic hernia ..... 18 ☐
Other musculoskeletal/integumental anomalies (Specify) _____ 19 ☐
Down's syndrome ..... 20 ☐
Other chromosomal anomalies (Specify) _____ 21 ☐
None ..... 00 ☐
Other _____ 22 ☐
(Specify)

DEPARTMENT OF HEALTH AND HUMAN SERVICES – PUBLIC HEALTH SERVICE – CENTERS FOR DISEASE CONTROL
NATIONAL CENTER FOR HEALTH STATISTICS – 1989 REVISION

CDC 64.91
REV. 1/89

Figure C1: U.S. Standard Certificate of Live Birth: 1989 Revision (Continued)



U.S. STANDARD CERTIFICATE OF LIVE BIRTH

LOCAL FILE NO. BIRTH NUMBER:

CHILD

1. CHILD'S NAME (First, Middle, Last, Suffix)
2. TIME OF BIRTH (24 hr)
3. SEX
4. DATE OF BIRTH (Mo/Day/Yr)
5. FACILITY NAME (If not institution, give street and number)
6. CITY, TOWN, OR LOCATION OF BIRTH
7. COUNTY OF BIRTH

MOTHER

8a. MOTHER'S CURRENT LEGAL NAME (First, Middle, Last, Suffix)
8b. DATE OF BIRTH (Mo/Day/Yr)
8c. MOTHER'S NAME PRIOR TO FIRST MARRIAGE (First, Middle, Last, Suffix)
8d. BIRTHPLACE (State, Territory, or Foreign Country)
9a. RESIDENCE OF MOTHER-STATE
9b. COUNTY
9c. CITY, TOWN, OR LOCATION
9d. STREET AND NUMBER
9e. APT. NO.
9f. ZIP CODE
9g. INSIDE CITY LIMITS? □ Yes □ No

FATHER

10a. FATHER'S CURRENT LEGAL NAME (First, Middle, Last, Suffix)
10b. DATE OF BIRTH (Mo/Day/Yr)
10c. BIRTHPLACE (State, Territory, or Foreign Country)

CERTIFIER

11. CERTIFIER'S NAME: _____
TITLE: □ MD □ DO □ HOSPITAL ADMIN. □ CNM/CM □ OTHER MIDWIFE
□ OTHER (Specify)_____
12. DATE CERTIFIED _____/ _____ / _____ MM DD YYYY
13. DATE FILED BY REGISTRAR _____/ _____ / _____ MM DD YYYY

INFORMATION FOR ADMINISTRATIVE USE

MOTHER

14. MOTHER'S MAILING ADDRESS: 9 Same as residence, or: State: City, Town, or Location:
Street & Number: Apartment No.: Zip Code:
15. MOTHER MARRIED? (At birth, conception, or any time between) □ Yes □ No
IF NO, HAS PATERNITY ACKNOWLEDGEMENT BEEN SIGNED IN THE HOSPITAL? □ Yes □ No
16. SOCIAL SECURITY NUMBER REQUESTED FOR CHILD? □ Yes □ No
17. FACILITY ID. (NPI)
18. MOTHER'S SOCIAL SECURITY NUMBER:
19. FATHER'S SOCIAL SECURITY NUMBER:

INFORMATION FOR MEDICAL AND HEALTH PURPOSES ONLY

MOTHER

20. MOTHER'S EDUCATION (Check the box that best describes the highest degree or level of school completed at the time of delivery)
□ 8th grade or less
□ 9th - 12th grade, no diploma
□ High school graduate or GED completed
□ Some college credit but no degree
□ Associate degree (e.g., AA, AS)
□ Bachelor's degree (e.g., BA, AB, BS)
□ Master's degree (e.g., MA, MS, MEng, MEd, MSW, MBA)
□ Doctorate (e.g., PhD, EdD) or Professional degree (e.g., MD, DDS, DVM, LLB, JD)

21. MOTHER OF HISPANIC ORIGIN? (Check the box that best describes whether the mother is Spanish/Hispanic/Latina. Check the "No" box if mother is not Spanish/Hispanic/Latina)
□ No, not Spanish/Hispanic/Latina
□ Yes, Mexican, Mexican American, Chicana
□ Yes, Puerto Rican
□ Yes, Cuban
□ Yes, other Spanish/Hispanic/Latina
(Specify)_____

22. MOTHER'S RACE (Check one or more races to indicate what the mother considers herself to be)
□ White
□ Black or African American
□ American Indian or Alaska Native (Name of the enrolled or principal tribe)_____
□ Asian Indian
□ Chinese
□ Filipino
□ Japanese
□ Korean
□ Vietnamese
□ Other Asian (Specify)_____
□ Native Hawaiian
□ Guamanian or Chamorro
□ Samoan
□ Other Pacific Islander (Specify)_____
□ Other (Specify)_____

FATHER

23. FATHER'S EDUCATION (Check the box that best describes the highest degree or level of school completed at the time of delivery)
□ 8th grade or less
□ 9th - 12th grade, no diploma
□ High school graduate or GED completed
□ Some college credit but no degree
□ Associate degree (e.g., AA, AS)
□ Bachelor's degree (e.g., BA, AB, BS)
□ Master's degree (e.g., MA, MS, MEng, MEd, MSW, MBA)
□ Doctorate (e.g., PhD, EdD) or Professional degree (e.g., MD, DDS, DVM, LLB, JD)

24. FATHER OF HISPANIC ORIGIN? (Check the box that best describes whether the father is Spanish/Hispanic/Latino. Check the "No" box if father is not Spanish/Hispanic/Latino)
□ No, not Spanish/Hispanic/Latino
□ Yes, Mexican, Mexican American, Chicano
□ Yes, Puerto Rican
□ Yes, Cuban
□ Yes, other Spanish/Hispanic/Latino
(Specify)_____

25. FATHER'S RACE (Check one or more races to indicate what the father considers himself to be)
□ White
□ Black or African American
□ American Indian or Alaska Native (Name of the enrolled or principal tribe)_____
□ Asian Indian
□ Chinese
□ Filipino
□ Japanese
□ Korean
□ Vietnamese
□ Other Asian (Specify)_____
□ Native Hawaiian
□ Guamanian or Chamorro
□ Samoan
□ Other Pacific Islander (Specify)_____
□ Other (Specify)_____

Mother's Name | Mother's Medical Record No.

26. PLACE WHERE BIRTH OCCURRED (Check one)
□ Hospital
□ Freestanding birthing center
□ Home Birth: Planned to deliver at home? 9 Yes 9 No
□ Clinic/Doctor's office
□ Other (Specify)_____

27. ATTENDANT'S NAME, TITLE, AND NPI
NAME: _____ NPI:_____
TITLE: □ MD □ DO □ CNM/CM □ OTHER MIDWIFE
□ OTHER (Specify)_____

28. MOTHER TRANSFERRED FOR MATERNAL MEDICAL OR FETAL INDICATIONS FOR DELIVERY? □ Yes □ No
IF YES, ENTER NAME OF FACILITY MOTHER TRANSFERRED FROM:
_____

REV. 11/2003

Figure C2: U.S. Standard Certificate of Live Birth: 2003 Revision

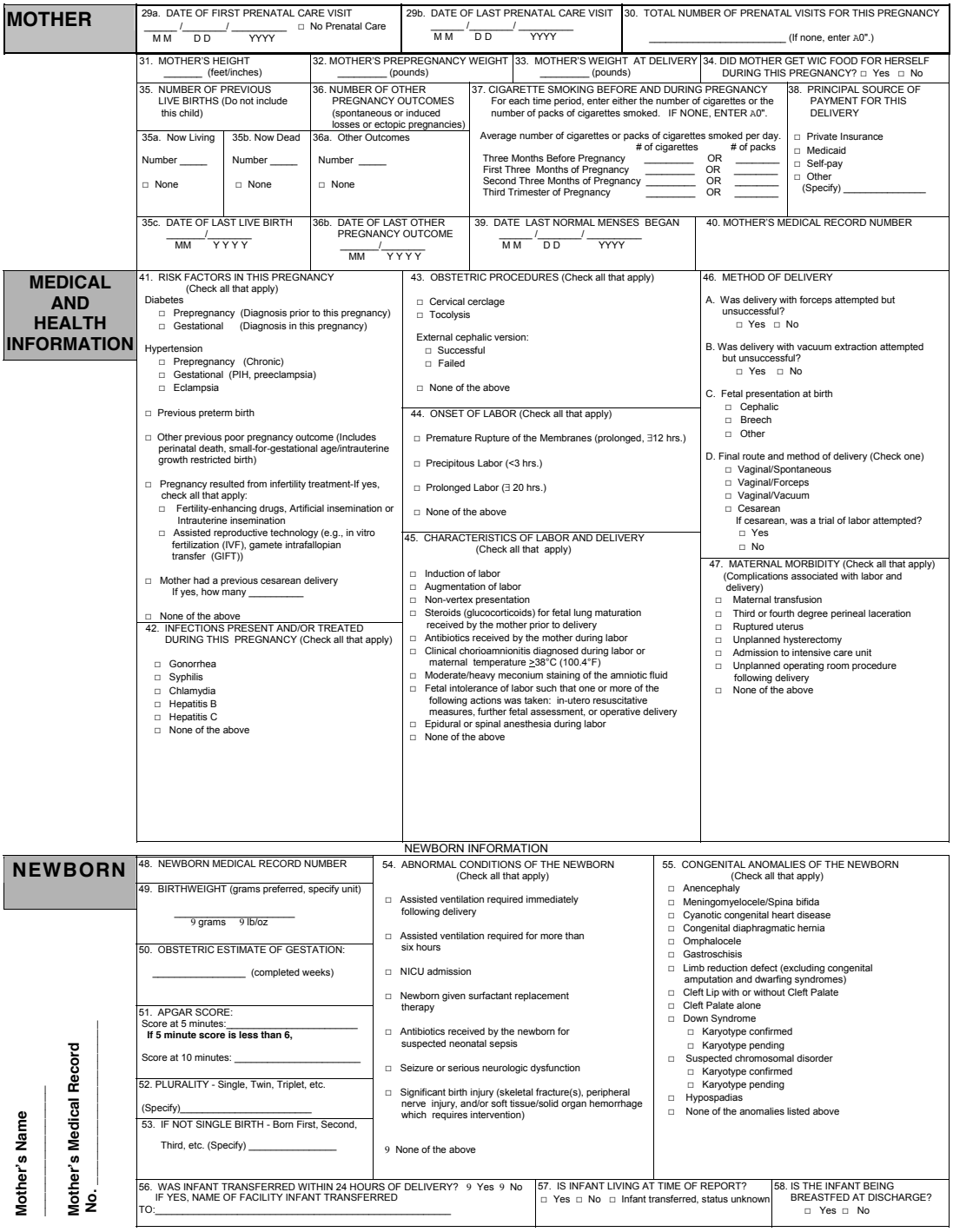


Figure C2: U.S. Standard Certificate of Live Birth: 2003 Revision (Continued)

Table C1: Implementation of the 2003 U.S. Standard Certificate of Live Birth, 2003–2013

Year	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003
Total	42 states and DC	39 states and DC	38 states and DC	35 states and DC	30 states	27 states	24 states	19 states	13 states	9 states	2 states
Alabama											
Alaska	X										
Arizona											
Arkansas											
California	X	X	X	X	X	X	X	X			
Colorado	X	X	X	X	X	X	X				
Connecticut											
Delaware	X	X	X	X	X	X	X	X			
District of Columbia	X	X	X	X	X						
Florida	X	X	X	X	X	X	X	X	X	X	
Georgia	X	X	X	X	X	X	X				
Hawaii											
Idaho	X	X	X	X	X	X	X	X	X	X	
Illinois	X	X	X	X							
Indiana	X	X	X	X	X	X	X				
Iowa	X	X	X	X	X	X	X				
Kansas	X	X	X	X	X	X	X	X	X		
Kentucky	X	X	X	X	X	X	X	X	X	X	
Louisiana	X	X	X	X							
Maine	X										
Maryland	X	X	X	X							
Massachusetts	X	X	X								
Michigan	X	X	X	X	X	X	X				
Minnesota	X	X	X								
Mississippi	X										
Missouri	X	X	X	X							
Montana	X	X	X	X	X	X					
Nebraska	X	X	X	X	X	X	X	X	X		
Nevada	X	X	X	X	X						
New Hampshire	X	X	X	X	X	X	X	X	X	X	
New Jersey											
New Mexico	X	X	X	X	X	X					
New York (excluding NYC)	X	X	X	X	X	X	X	X	X	X	
New York City	X	X	X	X	X	X					
North Carolina	X	X	X	X							
North Dakota	X	X	X	X	X	X	X	X			
Ohio	X	X	X	X	X	X	X	X			
Oklahoma	X	X	X	X	X						
Oregon	X	X	X	X	X	X					
Pennsylvania	X	X	X	X	X	X	X	X	X	X	X
Rhode Island											
South Carolina	X	X	X	X	X	X	X	X	X	X	
South Dakota	X	X	X	X	X	X	X	X			
Tennessee	X	X	X	X	X	X	X	X	X	X	
Texas	X	X	X	X	X	X	X	X	X		
Utah	X	X	X	X	X						
Vermont	X	X	X	X	X	X	X	X	X		
Virginia	X	X									
Washington	X	X	X	X	X	X	X	X	X	X	X
West Virginia											
Wisconsin	X	X	X								
Wyoming	X	X	X	X	X	X	X	X			

ABOUT THE AUTHOR

Prior to her doctoral study, Olga Petrova graduated with B.B.A. (summa cum laude) in Economics from St. Petersburg State University in St. Petersburg, Russia, and M.A. in Economics and M.S. in Finance from University of South Florida. Her research interests are in the general areas of health economics, economic development, and public policy.