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Outcomes of Midwife- Versus Physician-Attended Births: Unpacking Variation by Race and Place

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ABSTRACT

Midwives have been proposed as a potential avenue to combat adverse birth outcomes and severe racial disparities in maternal and child health in the United States, though policies that define midwives' role vary widely between states. Few studies have evaluated how birth attendant type affects birth outcomes, or how midwifery policies across states influence this relationship. Drawing from national birth records, I (1) test the association between birth attendant (physician or midwife) and birth outcomes, (2) evaluate whether these associations vary by maternal race/ethnicity, and (3) explore if state-level midwifery policies impact these relationships. Even after controlling for the different risk profiles of physician- and midwife-attended births, I find that midwife attendant is associated with lower odds of various adverse outcomes. Midwives are particularly protective against some of these outcomes for Black mothers relative to White mothers. Moreover, states with integrative midwifery policy tend to have higher average birthweights than states with more restrictive policy. A more comprehensive effort to integrate midwives into the healthcare system may help advance maternal and child health and health equity in the US.

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I. INTRODUCTION

The US consistently ranks behind comparably wealthy countries on many measures of maternal and child health (MCH), and jarring racial disparities in MCH persist (Melillo, 2020). One underlying difference between the US and other high-income countries with far better birth outcomes is the starkly different role midwives play in maternal care (Goodman, 2007). The midwifery model of care aims to minimize unnecessary interventions and tends to not only the physical but also psychological and social wellbeing of mothers (Rooks, 2019). Midwives dominated MCH care for much of history, supporting mothers and fostering a cooperative care environment. This contrasts the heavily medicalized physician model of care that currently dominates experiences of pregnancy and childbirth in the US. These medicalized, intervention-heavy norms in MCH have proven detrimental. Notoriously, our national caesarean rate (32%) is more than double the optimal rate recommended by the World Health Organization (10 to 15%), not to mention, the rate among Black women is higher than any other group (WHO, 2015).

Physician-led care typically emphasizes reducing risk of morbidity and mortality through the diagnosis and treatment of complications as they arise. The physician model takes a standardized approach, often applying medical intervention to correct deviations from a set norm. On the other hand, midwifery care focuses on holistic wellbeing, helping to strengthen mothers' ability to care for themselves and their children, while building mutual trust by providing encouragement and a supportive presence throughout. Midwifery has grown in popularity and scope in recent years, but few empirical analyses have examined differences in national birth outcomes by birth attendant.

Recent decades have seen a growing number of pregnant mothers seeking midwifery care, for a plethora of reasons. The natural birth movement has gained traction in response to the ubiquitously medicalized and often paternalistic approach to pregnancy and childbirth in the US. In a time when pregnancy is pathologized, many mothers appreciate the autonomy and ability to lead decision-making in their own maternity care that the midwifery model offers (Vedam et al., 2019). Indeed, the percentage of midwife-attended births has steadily increased from 0.9% in 1975, to nearly 10% as of 2018 (Neal et al., 2019). This re-emergence of midwifery has been politically controversial, leaving much room for incentives and bias in research: the current research landscape surrounding midwife-led care is filled with countervailing interests and often conflicting findings (Sandall et al., 2016).

Questions also still abound about the potential role of midwives in addressing racial disparities in MCH. Some hypothesize that midwives' supportive, low-intervention care can be especially protective for mothers of color or mothers in positions of relative disadvantage and social vulnerability (Casey et al., 2017). However, other research suggests that midwifery may be too little, too late when it comes to attenuating the effects of the systemic inequalities that drive differences in MCH across race (Lu et al., 2010). Emerging policies propose to better integrate midwives into obstetric care to address racial disparities, but much more research is needed before investing in this approach.

As aforementioned, the already complex landscape of midwifery in the US is additionally complicated by variable state level policy. Policies that define midwives' role in maternal care vary widely from state to state. Some states incorporate and reimburse midwives as essential practitioners, while others constrain their autonomy with tactics ranging from restricted prescriptive authority and referral stipulations to physician supervision requirements and suboptimal Medicaid reimbursement policies. With nearly half of all births in the US being reimbursed by CHIP or Medicaid, there is much interest in midwifery as a potential opportunity to not just improve outcomes and equity, but reduce costs in healthcare as well. Associative studies do find that states with more restrictive policies have lesser access to midwives, but the implications of these findings for health disparities and overall costs remain to be seen (Yang et al., 2016; Vedam et al., 2018).

Though midwifery is thought to attenuate aspects of the prevailing physician model of care that disproportionately harm mothers of color (Attanasio et al., 2020; Lantz et al., 2007), my study offers an empirical test of this hypothesis. To advance the current state of the literature, my analysis bridges national birth outcomes data with data on midwifery policy across states to characterize the effect of midwives on birth outcomes, and additionally examine how this relationship may interact with state policy environments. Inverse probability weighted regressions are employed to analyze overall national associations between birth attendant, maternal race, and outcomes at the individual level. Given the pressing need to better understand how midwifery functions under different state policy constraints, I additionally outline a mixed model approach to investigate the relationship between state policy context, midwifery, and birth outcomes, with a particular focus on implications for mothers of color.

After controlling for differential risk profiles, I find midwife-attended births to have far lower odds of various adverse birth outcomes for all mothers. After parsing out the effect of birth attendant by maternal race/ethnicity, I find that midwives are particularly protective for Black mothers compared to White mothers. Moreover, states with more integrative midwifery policies have higher mean birthweights than states with more hostile policies in place. I then corroborate these modeled effect estimates with a more concrete test of a real-world policy change: Massachusetts's 2013 decision to change from a collaborative practice regulatory framework for midwives to an autonomous practice regulatory framework. I present a difference-in-differences analysis of this policy change, examining its effects on birthweights and racial disparities in birthweights across the state, relative to a set of control states that did not undergo any corresponding policy change.

Guiding Research Questions

Q1. Are birth outcomes different for physician-attended and midwife-attended births?

Q2. Does the effect of birth attendant on outcomes vary by maternal race/ethnicity?

Q3. Does state-level midwifery policy affect the association between birth outcomes and birth attendant, or the interactions between attendant and maternal race/ethnicity?

Q4. Did Massachusetts's 2013 decision to relax regulations that had previously required midwives to practice in collaboration with physicians affect state trends in birthweight?

II. HISTORY AND BACKGROUND

While this paper will not thoroughly explore the complex entanglement of race, gender, personhood, and the plethora of other factors encapsulated within the history of midwifery, I would like to preface my work with a brief overview of the histories and forces that underpin the state of obstetric care as we know it today. Sociologists, historians, anthropologists, and other scholars have done a fantastic job examining the history of midwifery in the United States already; I would like to provide just a brief summary to provide some necessary context and better explain the motivations of my study.

The history of MCH in the US is the history of midwifery: from colonial times to the 20th century, midwives attended a significant portion of births. In fact, midwife-attended home births made up about half of births as recently as 1900. However, the growing field of medicine continued to professionalize, and by 1930, the proportion of midwife-attended home births dropped to less than 15%. However, this shift in MCH did not occur uniformly across the nation. In fact, in 1935, more than half of all Black births were still being attended by midwives (Tandy, 1937). Southern Black families in particular relied heavily on midwives far into the 20th century – for instance, midwives attended about 88% of births to Black mothers in Mississippi in 1918. Immigrant women, too, often depended on midwives: in 1908, 86% of Italian-American births in Chicago were delivered by midwives (Tandy, 1937). Indeed, midwifery care was historically heavily utilized, especially by mothers in rural areas and mothers who belonged to marginalized groups that did not have easy access to hospitals and the then-burgeoning field of medicine.

Though medical advancements and specialized obstetric care grew in popularity over time, midwifery care remained the most accessible, trustworthy, or viable option for many. Moreover, these advances in medical research and gynecology often relied on the exploitation of vulnerable women's bodies. Cesarean sections, which are now hallmarks of medicalized childbirth, were first pioneered in Louisiana by a surgeon who operated solely on enslaved women in the early 1800s. As medical science and technology evolved throughout the 19th and 20th century, physicians employed a variety of political tactics to vilify and discredit midwifery, in order to establish themselves as the leading authority in MCH. Needless to say, these doctors were by and large White men, and the historical struggle between physician and midwives is inseparable from legacies of slavery and rampant racism in medicine. A newfound germ theory of disease also brought about an obsession with sanitation. Physicians and hospitals became symbols of safety and cleanliness, while rhetoric was spread about how midwives were incompetent, unclean, and unsafe in efforts to displace them and give doctors more legitimacy in the public eye. Thus, the so-called "midwifery controversy" was born, embroiling midwives in hostile legislation throughout the 20th century that nearly eradicated the midwifery tradition altogether.

Dr. Clifton Edgar, an obstetrics professor, referred to midwives in 1911 as “dark, dirty, ignorant, untrained, imcompetent women…she is evil, though a necessary evil, and must be controlled. We must save our women” (Goode, 2017). That same year, the health commissioner for New York City, Dr. Thomas Darlington, shared similar sentiments, writing that “the midwife is commonly employed…by the negro and alien populations as well as by many native born of foreign percentage…reports prove conclusively that the midwife…is dirty, ignorant, and totally unfit to discharge the duties for which she assumes” (Darlington, 1911). Joseph DeLee, a leading professor of obstetrics, also derided the profession, claiming that “the midwife is a relic of barbarism” (Delee, 1916). Such negative characterizations of midwives cannot be separated from race and racism. As for physicians, professional homogenization, standardization, and rising standards for entrance into medical school continued to offer more and more prestige to medicine and the obstetrics specialty. Male physicians and their socially-defined competence soon displaced midwives, who were largely women of color serving vulnerable populations.

In this rocky period of transition in maternal and child health care, many in the medical community regarded midwifery as a nuisance. It was a necessary evil, at least until pregnancy and childbirth were completely shifted into the jurisdiction of physicians. The Sheppard-Towner Act of 1921 provided federal funding to states to formalize midwifery training and licensure, specifically targeting Black midwives in the South who, at the time, represented the largest group of unregulated birth attendants (Morrison, 2010). With states now racializing the hiring of reproductive healthcare workers, the new regulations and licensure requirements continued to burden midwives and exclude Black women (Goodwin, 2020). In response to concerns about cleanliness, professionalism, and maternal and infant mortality, the 1920s also saw the establishment of nurse-midwifery, a profession distinct from traditional midwifery in that the role required dual training as a medical nurse. Pregnancy and childbirth had become entirely reconceptualized as something to be *managed*, rather than attended – women's reproductive health was now pathologized.

The Hill-Burton Act of 1946 allocated federal funds to construct hospitals in rural areas, and further catalyzed the nationwide shift towards in-hospital birth. It expanded access to hospitals, particularly for Black mothers, and the proportions of births that took place in hospitals jumped from 27% in 1935 to 96% in 1960. However, the later decades of the 20th century saw a counter-movement against medicalization, with nurse-midwives establishing their own professional organization (the American College of Nurse Midwives) in 1955. With the rise of the women's movement in the late 1960s and into the 1970s, CNMs and freestanding birth centers gained popularity as a safe alternative to the heavily medicalized and male-dominated approach to maternity care. In response, the American Medical Association lobbied for regulations that prohibited midwives from practicing without supervision – such policy restrictions persist today.

Today, midwives are mainly classified as certified nurse-midwives (CNMs), certified midwives (CMs), or certified professional midwives (CPMs). Each type of midwife undergoes a different accreditation process and faces different laws that govern their scope of practice. CNMs train dually as registered nurses and as midwives and are certified by the American Midwifery Certification Board. They are licensed and allowed to practice in every state in the US. Though CNMs most often work in hospital settings, they can practice in a variety of different settings ranging from the hospital to the home. CMs are also certified by the American Midwifery Certification Board, differing from CNMs in that they are not required to hold a nursing degree. CMs are only licensed in a few states, though there has been growing interest in CM licensure as a potential means to address some of the shortage in maternity care providers. As of 2020, there were 12,990 AMCB-certified midwives; 12,872 of which were CNMs, and 118 were CMs. (American Midwifery Certification Board, 2020).

CPMs are professionally independent practitioners and certified by the North American Registry of Midwives. While a nursing degree is not required, CPM certification involves validation of midwifery education. CPMs do not have prescriptive authority in any state, but can use devices and administer medications as permitted by state-specific laws. Many states in the US do not currently license CPMs to practice at all. There are approximately 2,600 active CPMs as of 2022, making up an estimated 1 in 5 midwives in the US (National Association of Certified Professional Midwives, 2022). CMs and CPMs are often collectively referred to as direct-entry midwives, as they are midwives that acquire credentials without first becoming a nurse. Unless otherwise specified, the term “midwife” in this paper will refer collectively to CNMs, CMs, and CPMs. Recognizing that individuals of all genders have the capacity for pregnancy and birth, the term “mother” in this paper refers broadly to all birthing people.

III. LITERATURE REVIEW

Many studies find midwife-attended births to be associated with lower rates of obstetrical interventions like caesareans and episiotomies (Attanasio & Kozhimannil, 2017; Benatar et al., 2013; Thornton, 2017; Jackson et al., 2003), and higher rates of spontaneous vaginal deliveries and vaginal birth after caesarean (VBAC) (Jackson et al., 2003). Midwife-attended births have also been associated with lower rates of infant death, low birth weight, and preterm birth. (MacDorman & Singh, 1998; McRae et al., 2018; Sandall et al., 2013). A Cochrane review of 15 randomized trials between midwife-led and other models of care found that mothers under midwife-led care were less likely to experience intervention, more likely to be satisfied with their care, and have at comparable if not lower rates of various adverse outcomes (Sandall et al., 2016). However, the review also demonstrated a lack of consensus on several outcomes such as caesarean birth, breastfeeding, low birth weight, and low Apgar scores. Indeed, many pressing questions concerning midwifery and MCH remain unresolved.

There are several pathways by which midwives might improve outcomes. It is hypothesized that emphasis on low-intervention care yields better health outcomes (not to mention overall lower costs of care) while the overmedicalization of physician-attended births might actually be detrimental to mothers, particularly mothers of color (Attanasio et al., 2020; Lantz et al., 2007). Midwives may also serve to protect mothers in hostile hospital environments, where risk aversion and scheduling pressures could otherwise trump patients' best interests.

However, determinants of MCH act far beyond just the moments of delivery. Racial discrimination, both in everyday lived experiences and within the health care system, has been linked to fewer prenatal visits, increased risk of preterm birth, and other health detriments (Holdt Somer et al., 2017; Salm Ward et al., 2013). However, the existence of these broader determinants means there are many opportunities to intervene and mitigate adverse outcomes. In one focus group, mothers cared for by midwives reported discussing more health promotion topics than those cared for by physicians and voiced appreciation for the relationships they formed with midwives they saw regularly, while contrastingly perceiving discontinuity of care and lack of connection with their physicians (Edmonds et al., 2015). Midwives are well positioned to respond to contextual factors when caring for patients; this practitioner-patient trust has been shown to be associated with continuity of care as well as adherence to clinical advice, particularly for women of lower socioeconomic positions (McRae, 2016). Indeed, patient-centered care, cultural congruency, and even longer care visits might better equip midwives to support mothers throughout pregnancy, reducing vulnerabilities to health sequelae of discrimination and other stressors that have been implicated in racial MCH disparities (Bogossian, 2007; Cox, 2009).

A separate body of literature examines the effects of scope of practice regulations, reimbursement protocols, and other restrictive policies on access to midwifery care. For instance, Medicaid beneficiaries have been found to have far less access to midwives relative to privately insured individuals, with birth centers often having to limit the number of Medicaid enrollees due to low reimbursement rates (Courtot et al., 2020). States with autonomous practice laws have been found to have more practicing midwives and more midwife-attended births per 1,000 births, compared to states where midwives are required to be in a collaborative practice agreement with physicians (Ranchoff & Declercq, 2020). States that score higher on the Midwifery Integration Scoring System (MISS), a metric that measures how well midwives are integrated into obstetric care, have also been found to have overall lower rates of preterm birth, cesareans, and neonatal death (Vedam et al., 2018).

Midwifery has been shown to be associated with improved birth outcomes, and circumvents many aspects of the dominant physician-led model of care that are currently known to disproportionately harm mothers of color; state-level regulation has been demonstrated to directly impact mothers' access to midwives. Yet, no single study has harmonized these distinct arenas of knowledge all at once. While most research on this subject has been associative in nature, the direction of causality between midwife-attended births and birth outcomes remains to be seen. My approach adjusts for potential confounders more rigorously than previous associative studies, in hopes of more clearly uncovering potential causal relationships between midwifery and birth outcomes. While some researchers have managed to carry out randomized studies of midwifery care, these studies tend to be limited in external validity, having only been conducted in a single city or in a small group of mothers who volunteered to participate (Harvey et al., 1996).

This study thus also presents an opportunity to investigate associations previously observed at a smaller scale or in a controlled environment hold true nationally. Current literature provides a strong conceptual basis for this work, which seeks to use probability weighted regressions and multilevel modeling, as well as a difference-in-differences analysis of recent national birth outcomes data. I build upon previous work by harmonizing knowledge linking midwifery to birth outcomes and disparities, while also taking state-level contexts into account.

IV. DATA

Data for this analysis is drawn from 2 sources: 1) National Vital Statistics System (NVSS) Natality Data files, and 2) the Midwifery Integration Scoring System (MISS) from the Access and Integration Maternity Care Mapping (AIMM) Study (Vedam et al., 2018).

Individual-level Data and Variables

The NVSS is the most comprehensive source of annual birth data in the US. I specifically draw from the 2014 dataset for the logistic and multilevel regression models, as the MISS score was computed according to policy contexts in 2014. However, for difference-in-differences analyses later on, I turn to NVSS data from 2000 through 2018. The Natality Data files include variables on demographic, geographic, and medical information for all births in the US, which are utilized to address each of the first three proposed research questions. The main independent variable is birth attendant, dichotomized as either physician or midwife. Though attendant at birth does not perfectly capture the full experience of care received throughout pregnancy, the majority of mothers who had midwives as their prenatal care provider also had a midwife as their birth attendant (Weisband et al., 2018).

The dataset's birth attendant variable is coded with the following categories: Doctor of Medicine (MD), Doctor of Osteopathy (DO), Certified Nurse Midwife (CNM), Other Midwife, Other, or Unknown. The first two categories are combined and coded as physician-attended; CNM and Other Midwife are combined and reclassified as midwife-attended. Remaining observations – which may correspond to doula-attended births, births where the attendant was unknown, etc. – are dropped. While it is true that CNMs and midwives with other certifications may operate in different capacities, the focus of the study is the two competing models of care, rather than specific certifications. Nevertheless, recognizing that different practice settings may confound the relationship of interest, differences in birth facility are accounted for through probability weights, exclusion criteria, and regression controls, as further outlined in the methodology section below.

Due to low sample size for certain groups, the analysis is limited to non-Hispanic White, non-Hispanic Black, and Hispanic (referred to here as Latina) identifying mothers. While the NVSS is a national dataset, some of the outcomes of interest are relatively uncommon, and issues of multicollinearity have arisen in preliminary models as the interaction term for certain maternal races/ethnicities with the birth attendant indicator variable were perfectly predicted. Dependent variables representing various birth outcomes are also be taken from the NVSS. Relevant sociodemographic and other characteristics in the data file are included as covariates in the models, and additionally used to generate propensity scores to weight the regressions.

Birth outcomes of interest were dichotomized for analysis using the following widely cited clinical cutoffs: preterm birth (gestational age <37 weeks), low and very low birth weight, (<2500 grams; <1500 grams), and low 5-minute Apgar score (<7). Additional dichotomized variables were created for caesarean delivery and vaginal birth after cesarean (VBAC).

State-level Data and Variables

Data on state-level policy climate to answer Question 3 is drawn from the MISS. The MISS used 50 weighted indicators of midwifery integration, including scope of practice laws, licensure requirements, and Medicaid reimbursement, to assign a score out of 100 for all 50 states and Washington DC based on conditions in 2014-2015. Table A1 provides a full outline of the indicators used to generate MISS scores. For this analysis, states are assigned to a MISS quartile based on this raw score; MISS quartiles are then incorporated as a state-level random effect.

Case Study Data

State-specific birthweight data is drawn from the 2000 to 2018 NVSS Natality Data files and used to examine the effects of Massachusetts's 2013 policy change. State-level covariates such as average maternal age, racial/ethnic composition, maternal education level, and percent singleton births were computed and included in the difference-in-differences model.

Table 1. Outline of Data and Methodology, by Research Question

Question	Data	Methods
Q1. Are birth outcomes different for physician-attended and midwife-attended births?	**NVSS 2014**	**Weighted logistic regression**
Q2. Does the effect of birth attendant on outcomes vary by maternal race/ethnicity?	**NVSS 2014**	**Weighted logistic regression**
Q3. Does state-level midwifery policy affect the association between midwife attendants and birth outcomes, or the interaction between maternal race and midwife attendants' effect on birth outcomes?	**NVSS 2014, MISS score**	**Weighted multilevel regression**
Q4. Did Massachusetts's 2013 decision to relax regulations that had previously required midwives to practice in collaboration with physicians affect state trends in birthweight?	**NVSS 2000-2018**	**Difference-in-differences**

V. METHODOLOGY

Data Cleaning and Exclusion Criteria

All data analysis was performed in STATA/SE 16.0. In 2014, the NVSS data files recorded 3,998,175 birth cases. Cases that were missing data on any of the covariates were dropped from the dataset. Additional exclusion criteria were also applied to better satisfy underlying assumptions of inverse probability weighting. The purpose of a propensity score weighting approach to estimate treatment effects is to mimic a randomized study. One key assumption of inverse probability weighting is positivity: each observation should have a nonzero probability of being assigned to either treatment group. As such, the analytical sample should comprise of cases that could have reasonably been attended by either physician or midwife. In the real world, women with higher-risk or atypical pregnancies may not have the option of a non-physician attendant (Declercq, 2015; Carlson, 2020). Knowing this, the analytical sample is limited to singleton births of infants with no known congenital anomalies, delivered by physicians or midwives to mothers with no history of diabetes, hypertension, or eclampsia, yielding an analytical sample size of n=2,593,795. Cases dropped from analysis did not differ significantly from cases that were retained.

Inverse Probability Weighting

Inverse probability weighted multivariate regression is conducted to explore the overall association between birth attendant and selected birth outcomes. However, mothers with midwife- versus physician-attended births in the sample may still differ on a variety of characteristics that, if unaccounted for, can confound effect estimates. Propensity score weighting is hence used to balance the overall distribution of potentially confounding variables between the two groups and account for treatment selection bias in the data and mimic a randomized trial. A propensity score represents the conditional probability of assignment to a treatment condition (in this case, midwife attendance), given a set of observable covariates. This is formulaically represented as:

$$\mathbf{p_i = P(Z_i = t \mid X)}$$

where **p** is the expected probability of treatment **t**, conditional on covariates **X** for each case **i**. I compute the propensity scores **p** using a logistic regression predicting treatment status from a set of covariates, including maternal age, race/ethnicity, education level, smoking status, nativity, marital status, birth facility, county population, prenatal care utilization, WIC participation, insurance, parity, BMI, previous preterm, previous cesarean, and pregnancy weight gain.

Propensity scores can be applied to data in many ways to improve covariate balance and create a more level comparison between treated and control groups, including via matching and weighting. An advantage of weighting methods over propensity matching is that they allow for the inclusion of all data points. In this case, because the sample size for certain combinations of characteristics of interest is limited, it is preferable to keep as many observations in the analytical dataset as possible. Weights were calculated using the following equation:

$$\mathbf{w_i = \frac{Z_i}{p_i(X)} + \frac{1 - Z_i}{1 - p_i(X)}}$$

where $\mathbf{p_i(X)}$ represents the estimated propensity score, and $\mathbf{Z_i}$ is the treatment indicator (0 or 1). With this equation, treated (midwife-attended) births are weighted with the inverse of their propensity score, while control (physician-attended) births are weighted with the inverse of their respective propensity scores subtracted from one. Formulaically, $\mathbf{w_i} = \frac{\mathbf{1}}{\mathbf{1-p_i(X)}}$ when $\mathbf{Z_i} = 0$**,** while $\mathbf{w_i} = \frac{\mathbf{1}}{\mathbf{p_i(X)}}$ when $\mathbf{Z_i} = 1$**.** In taking the inverse probability of treatment, this approach down-weights characteristics overrepresented in the treated group, an approach that has proven to be powerful in comparative effectiveness studies using observational data (Curtis et al., 2007).

Exchangeability is a key assumption for causal inference, requiring that treatment groups have the same distribution of potential outcome, independent of treatment effect. However, this assumption is not easily met. In the presence of factors **X** that confound the relationship between the outcome **Y** and the treatment **Z**, $\mathbf{P(Z \mid X) \neq P(Z)}$. In the raw data, we observe distributions of the treatment conditional on confounders. By the definition of confounding, this observed probability is not equal to $\mathbf{P(Z)}$ alone. A workaround is that of *conditional* exchangeability: if exchangeability holds within each stratum of the confounders, then conditioning on these variables removes confounding effects. In reweighting by the inverse probability of treatment, $\mathbf{w_i}$, we create a pseudo-population where assignment to treatment group is no longer associated with measurable confounders **X**. Thus, the weighted data should in principle meet the exchangeability criteria.

In context, treated cases with traits that are strongly selected for among midwife-attended births (for instance, births at a free-standing birth center) are downweighted, while treated cases whose profiles are less common in the treated group (for instance, mothers who reported a previous cesarean) are upweighted. The same is true for control cases: those with a higher predicted propensity of being physician-attended (Z = 0) are downweighted, while those with a lower predicted propensity of being physician-attended are upweighted. The overall result is a heavier emphasis on observations in the data that that better represent the missing potential outcomes for the other treatment group. If all assumptions are met, we are hence able to isolate the true probabilities and effects of treatment, independent of confounding variables. In this way, the weights allow us to better mimic experimental conditions and compute true effect estimates.

Logistic Regression Models

After computing and applying weights, separate models test the association between birth attendant and various birth outcomes, with the generic formula being as follows:

$$\mathbf{Y_i = \beta_0 + \beta_1(Z_\mathit{i}) + \beta_i X_i}$$

where $\mathbf{Y_i}$ represents the log odds of the chosen outcome, $\mathbf{Z_i}$ represents the treatment received for a particular case, and $\mathbf{X_i}$ is the vector of all covariates. Covariates in this outcome model are the same as those used to determine propensity scores. This doubly robust method of estimation, where covariates are used in both propensity score generation and the outcome regression, allows for accurate estimation, even if one stage of the regression models is not perfectly specified (Bang & Robins, 2005; Emsley et al., 2008).

To test whether the association between birth attendant and birth outcomes varies by maternal race/ethnicity, interaction terms between each maternal race/ethnicity category (White, Black, Latina/Hispanic) and birth attendant are then introduced into the base models. The fitted coefficients on each interaction term help discern whether the effect of birth attendant on each outcome significantly differs by maternal race/ethnicity. Because logistic regression coefficients and their corresponding odds ratios are tedious to interpret, especially once interaction terms are added to the mix, I also provide plots of the marginal effect of midwife attendant on overall predicted probabilities of each birth outcome to aid interpretation.

Multilevel Model

To evaluate whether state-level midwifery policy impacts the individual-level associations, a multilevel model is used to test how state-level factors modulate (a) the association between midwife-attended births and birthweight, and (b) the association between mother's race and midwife-attendance with birthweight. Multilevel modeling is designed to account for potential clustering within data and enables the inclusion of independent variables at both group and individual levels of the data. In this case, birth cases are nested within states and their respective policy climates.

Random state effects are preferable over fixed effects in the case of this analysis, as random effect models treat group-level effects as being randomly sampled from a normal distribution, while fixed effect models treat clusters as being unrelated. Fixed effects account for all group-level variance in the model and would thus make the measurement of the effect of state-level MISS score difficult. Furthermore, the analytical dataset is large, containing many clusters and observations, such that the bias that may result from partial pooling in a random effects approach would not be substantial. The quantile-quantile plot and histogram presented in Figures A2 and A3 in the Appendix also confirm the assumption that random effects of state on birthweights do indeed follow an approximately normal distribution, suggesting that a mixed model with random effects is appropriate.

Data remains weighted with the same set of probability weights as before. Simulation studies have found that scores computed using regressions that ignore clustering are satisfactory, so long as the clustered structure of data is accounted for in the outcome model, as it is here (Leite et al., 2015; Li et al., 2013). Repeat analyses are also conducted using multilevel propensity score models and different specifications to ensure an adequate model is chosen. The generic formula for the multilevel model is as follows:

Level 1: $\mathbf{Y_{ij}} = \mathbf{b_{0j}} + \mathbf{b_{1j}}(\mathbf{X_{ij}}) + \boldsymbol{\epsilon}_{\mathbf{ij}} \qquad \epsilon_{ij} \sim \mathrm{NID}(0, \sigma^2)$

Level 2: $\mathbf{b_{0j}} = \boldsymbol{\beta}_{\mathbf{0}} + \boldsymbol{\beta}_{\mathbf{2}}(\mathbf{S_j}) + \boldsymbol{\upsilon}_{\mathbf{0j}} \qquad \upsilon_{0j} \sim \mathrm{NID}(0, {\sigma_\upsilon}^2)$

$\mathbf{b_{1j}} = \boldsymbol{\beta}_{\mathbf{1}}$

where **j** is the index for states and **i** is the index for birth cases within each state. $\mathbf{Y_{ij}}$ represents the birthweight for each individual birth case, $\mathbf{X_{ij}}$ represents the vector of individual-level covariates and $\mathbf{S_j}$ represents the vector of state-level covariates. $\mathbf{b_{0j}}$ represents the random intercept (i.e. the mean birthweight in state **j**), $\boldsymbol{\beta_0}$ represents the weighted mean of outcomes in the dataset, $\boldsymbol{\beta_1}$ represents the vector of parameter estimates for individual-level covariates, and $\boldsymbol{\beta_2}$ represents the vector of parameter estimates for each state-level covariate. $\boldsymbol{\epsilon_{ij}}$ represents the residuals for each birth case **j** in state **i**, describing how birth **j** differs from the average birthweight in that state, while $\boldsymbol{\upsilon_{0j}}$ represents the random effect of birth cases clustering by state on outcome; this term accounts for differences between state means and overall means.

I first assess if birth attendant is associated with birthweight, accounting for state-level variability via random intercept. To test whether state policy environments modify the association between birth attendant and birth outcomes, states' MISS score quartiles are also added as a state-level effect. The model is again adjusted for the same covariates as before, and includes the midwife and maternal race/ethnicity interaction terms. The fixed and random effect estimates, as well as the variance parameters and intraclass correlation are interpreted.

Case Study

An inevitable limitation of probability weighting and regression control approaches is the possibility of unobservable variables that remain unaccounted for and confound results. In an effort to move beyond these constraints and test if modeled results hold true in a real-world setting, I employ a difference-in-differences regression analysis of a 2013 midwifery policy change in Massachusetts. Tracking trends in average birthweight across several years pre- and post-policy in Massachusetts, I then compare them to those of a pooled set of control states that did not experience a commensurate midwifery policy reform between 2000 and 2018. Though the policy of interest was enacted in 2013, 2014 is the cutoff used to code the post-policy indicator, to better account for time lags in the effects of such a policy in the workforce. This cutoff also makes more sense considering pregnant individuals' exposure to the policy and its full effects may not have be immediately reflected in birthweights that same year: gestation lasts for an average of 40 weeks, and mothers are typically in contact with practitioners throughout pregnancy, not just at delivery.

A difference-in-differences approach allows for the control of some unobservable confounding effects, and I can thus estimate the isolated treatment effect of this policy change on birthweights and associated racial disparities. Difference-in-differences analyses account for time-invariant differences between the treatment and control group, while also parsing out the effect of the policy change of interest from effects of other time-varying factors. Here, I control for percent White/Black/Latina mothers, average maternal age, average maternal education level, percent male births, and percent singleton births for each state. As the treatment of interest for this sub-aim is now between-states rather than within-states, the 2000 to 2018 NVSS data is not weighted.

The formula for the difference-in-differences regression model is:

$$\mathbf{Y_i = \beta_0 + \beta_1(MA * Post) + \beta_2(MA) + \beta_3(Post) + \beta_i X_i}$$

Here, $\mathbf{Y_i}$ represents group mean birthweight – Massachusetts, or the pooled control states. **MA** serves as the treatment group indicator, coded as 1 for Massachusetts, and 0 for the pooled control, and $\boldsymbol{\beta_2}$ hence represents the mean difference in birthweights between the two groups pre-policy. **Post** is coded as 0 for all data before 2014, and 1 for data points from 2014 onwards, with $\boldsymbol{\beta_3}$ representing the difference mean birthweights for the entire dataset before and after 2014. $\mathbf{X_i}$ is the vector of all covariates, and $\boldsymbol{\beta_i}$ is the vector of parameter estimates for each of their effect estimates. $\boldsymbol{\beta_1}$ is the main parameter of interest, capturing the difference in observed mean birthweights in Massachusetts post-2014 from the expected mean, had state-level trends followed those of the pooled control. If the parallel trends assumption holds, $\boldsymbol{\beta_1}$ represents the effect of the policy change on birthweights in Massachusetts.

VI. RESULTS

Descriptive statistics

Table 1 describes characteristics in the overall unweighted sample, as well as by birth attendant. Approximately 10% of births in the sample were attended by midwives, and 90% by physicians. Comparing characteristics of physician- versus midwife-attended births by performing chi-square tests and t-tests, I find the two groups differ significantly across nearly all key characteristics. White mothers were overrepresented, while Black and Latina mothers were underrepresented in midwife-attended cases. Mothers seeking midwifery care were also slightly higher educated and more likely to be married, and less likely to be insured by Medicaid, have ever smoked, or have had a previous preterm birth or cesarean.

A raw comparison of rates of adverse birth outcomes such as preterm birth (PTB), low/very low birthweight (LBW/VLBW), and low Apgar score indicates that midwife-attended births are less likely to experience these adverse outcomes. Physician-attended births were far more likely to be via cesarean section, and less likely to be a vaginal birth after previous cesarean. Cursory associative analysis suggests that midwife-attended births do indeed fare better overall. However, knowing that risk profiles and confounding characteristics differ depending on birth attendant, no conclusions can be drawn about the actual effect of midwifery itself on birth outcomes yet. To attempt to overcome some of this selection bias based on observable characteristics, inverse probability weights were generated and applied to the data.

Figure 1. Propensity score distribution before and after weighting

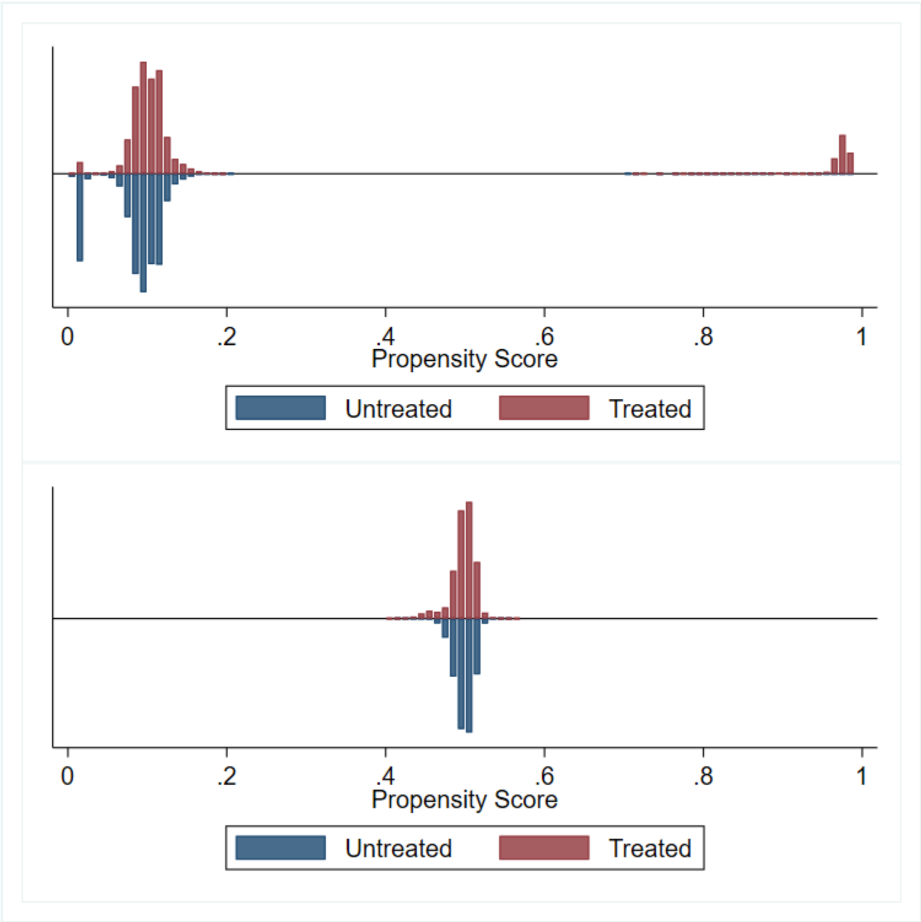


Figure 1 offers a visual representation of the balancing effect of this technique. Before weighting, the bulk of propensity scores for both the treated and untreated groups are clustered around 0.1. Considering the vast majority of births were physician-attended, it makes sense that the propensity score (i.e. the probability of having a midwife attendant) is skewed towards 0, regardless of treatment arm. Notably, small portions of each group are clustered at their respective extremes: there is a cluster of treated observations with a propensity sore of nearly 1, and a cluster of untreated observations with a propensity score of nearly 0. While inverse probability weights can be unstable if predicted propensities are small, there are relatively few extremely high or low propensity scores, and hence skewed weights do not pose a significant concern.

After weighting the data, the distributions of propensity scores for across both groups become nearly identical and centered around 0.5. That is, in the pseudo-population created via inverse probability weighting, physician and midwife-attended births have approximately equal propensities of having received either treatment. Tables A1 and A2 present more detailed summary statistics, demonstrating the balancing effect of this weighting on the actual risk profiles and other key characteristics. Table 2, below, offers a summary of test statistics for the unweighted and weighted datasets. While some group differences remain significant after weighting, the magnitude of the test statistics decrease greatly for all covariates, indicating that the distribution of characteristics of both groups is not as starkly different as it is in the unweighted data.

Table 2. Comparison of test statistics for unweighted and weighted data

	Unweighted dataset	Weighted dataset
	t or χ^2	
Age	-9.66***	1.11
Race	19.13***	1.79
Education	372.39***	24.25***
Facility	182.16***	5.92**
Prenatal care start	29.74***	1.60
County population	307.11***	20.55***
BMI	-69.94***	-8.88**
Ever smoke	117.68***	23.92***
Pre-pregnancy weight	-54.09***	-7.95**
Married	83.35***	16.82***
Medicaid	151.57***	30.25***
Private insurance	256.08***	51.24***
WIC	181.10***	36.68***
Previous cesarean	132.03***	8.62**
Previous preterm birth	59.37***	7.930**
Birthweight	87.48***	50.91***
Preterm birth	8212.89***	1442.08***
Low birthweight	9671.06***	1432.34***
Very low birthweight	5996.75***	387.61***
Low Apgar score	1755.39***	297.92***
Cesarean	~37710***	~18100***
VBAC	~121000***	~29900***

***signifies p<0.05, ** signifies p<0.01, *** signifies p<0.001**

Note: t-tests used for continuous variables, chi-square tests used for categorical variables

Logistic Regression Models

Regressions on the weighted data examining the effect of midwives on the six birth outcomes of interest, controlling for race, age, education, marital status, insurance type, WIC receipt, BMI, weight, smoking status, prenatal care start time, county population, birth facility, pregnancy weight, previous cesarean procedure, and previous preterm birth were performed; resulting coefficients are presented in Table 3, with their corresponding odds ratios reported below.

Table 3. Regression results: baseline model

(a) Regression coefficients and z-values

	Preterm birth	**Low birthweight**	**Very low birthweight**	**Low Apgar**	**Cesarean**	**VBAC**
Midwife	-0.327**	-0.647**	-1.681**	-0.292**	-3.796**	4.304**
	(38.25)	(38.65)	(17.70)	(16.38)	(140.52)	(95.58)
Maternal race: Black	0.461**	0.810**	1.065**	0.229**	0.145**	-0.160
	(38.03)	(42.94)	(22.56)	(9.29)	(10.77)	(1.95)
Maternal race: Latina	0.171**	0.022	0.226**	-0.303**	-0.084**	-0.063
	(15.75)	(1.17)	(4.86)	(11.75)	(7.55)	(0.98)

(b) Odds ratios and standard errors

	Preterm birth	**Low birthweight**	**Very low birthweight**	**Low Apgar**	**Cesarean**	**VBAC**
Midwife	0.724**	0.528**	0.188**	0.748**	0.052**	9.726**
	(0.006)	(0.009)	(0.018)	(0.013)	(0.001)	(0.153)
Maternal race: Black	1.608**	2.284**	2.973**	1.260**	1.201**	1.241
	(0.019)	(0.043)	(0.141)	(0.031)	(0.001)	(1.143)
Maternal race: Latina	1.178**	1.014	1.237**	0.738**	0.956**	0.928*
	(0.013)	(0.019)	(0.058)	(0.02)	(0.009)	(0.035)

***signifies p<0.05, ** signifies p<0.01**

Note: maternal age, education, marital status, insurance type, WIC receipt, BMI, weight, smoking status, prenatal care start time, county population, birth facility, pregnancy weight gain, previous cesarean procedure, and previous preterm birth were included as covariates in all models, but their corresponding estimates are not reported above

In the baseline model, midwife-attended births were found to have significantly lower odds of being preterm, low birthweight, very low birthweight, low Apgar, or cesareans, and (for mothers with previous cesareans) vaginal births after cesareans. Moreover, Black mothers had overall far greater odds of experiencing any of the adverse birth outcomes. Latina mothers, too, had elevated odds of preterm birth, very low birthweight, and low Apgar score (Table 3a).

Introducing an interaction between maternal race/ethnicity and birth attendant reveals that there is a significant interaction between Black maternal race and midwife attendant across all outcomes, except preterm birth and VBAC (Table 4). Interactions between Latina mothers and midwife attendant are similarly significant for preterm birth, low birthweight, very low birthweight, and VBAC. The directions of these interaction terms, however, varied. That is, the relative effect of midwives on odds of these birth outcomes varied significantly depending on maternal race/ethnicity; for some outcomes, midwives were more protective for White mothers, while for others, they were more protective for Black or Latina mothers.

*Table 4. Regression results: model with midwife*maternal race/ethnicity interaction*

(a) Regression coefficients and z-values

	Preterm birth	**Low birthweight**	**Very low birthweight**	**Low Apgar**	**Cesarean**	**VBAC**
Midwife	-0.386**	-0.683**	-1.888**	-0.244**	-3.864**	4.350**
	(34.33)	(30.73)	(13.31)	(11.53)	(105.07)	(73.21)
Maternal race: Black	0.413**	0.767**	0.981**	0.332**	0.103**	0.099**
	(54.16)	(61.74)	(30.19)	(20.33)	(14.09)	(2.67)
Maternal race: Latina	0.111**	0.016	0.222**	-0.303**	-0.089**	-0.131**
	(13.83)	(1.16)	(6.59)	(17.53)	(11.09)	(3.15)
Midwife*Black	0.107**	0.119**	0.510*	-0.254**	0.303**	-0.473**
	(4.50)	(2.82)	(2.47)	(4.81)	(3.78)	(3.87)
Midwife*Latina	0.136**	0.020	0.051	-0.003	0.048	0.136
	(6.83)	(0.48)	(0.19)	(0.07)	(0.66)	(1.22)

(b) Odds ratios and standard errors

	Preterm birth	**Low birthweight**	**Very low birthweight**	**Low Apgar**	**Cesarean**	**VBAC**
Midwife	0.681**	0.506**	0.151**	0.784**	0.050**	9.859**
	(0.01)	(0.01)	(0.02)	(0.02)	(0.00)	(0.195)
Maternal race: Black	1.528**	2.178**	2.723**	1.395**	1.156**	1.327**
	(0.01)	(0.03)	(0.09)	(0.02)	(0.01)	(0.03)
Maternal race: Latina	1.107**	1.004	1.229**	0.737**	0.962**	0.931**
	(0.01)	(0.01)	(0.04)	(0.01)	(0.01)	(0.02)
Midwife*Black	1.12**	1.138**	1.702*	0.777**	1.374**	0.926**
	(0.03)	(0.05)	(0.35)	(0.04)	(0.10)	(0.04)
Midwife*Latina	1.152**	1.030	1.070	0.999	0.950	0.995
	(0.02)	(0.043)	(0.29)	(0.05)	(0.06)	(0.04)

***signifies p<0.05, ** signifies p<0.01**

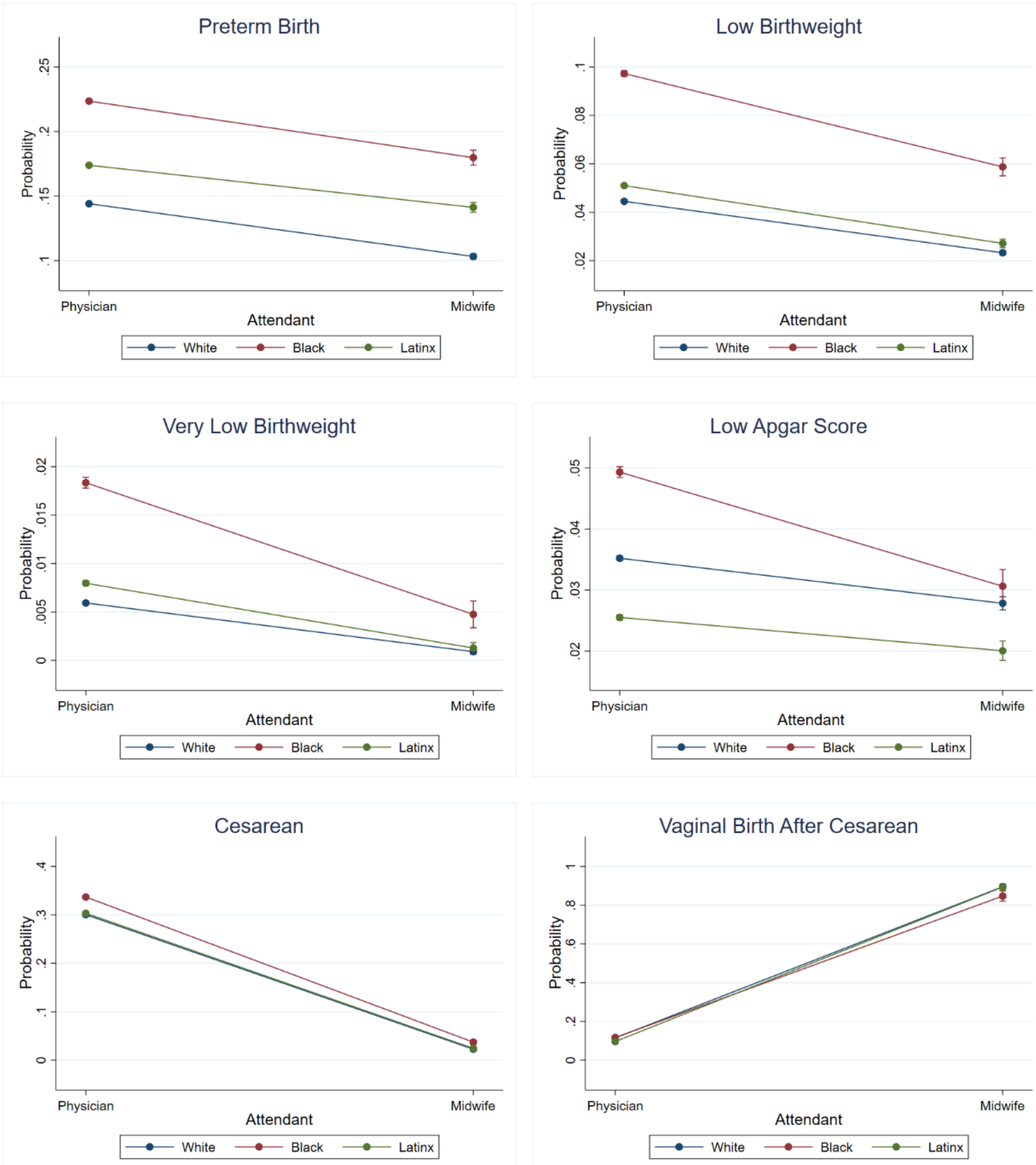
Note: maternal age, education, marital status, insurance type, WIC receipt, BMI, weight, smoking status, prenatal care start time, county population, birth facility, pregnancy weight gain, previous cesarean procedure, and previous preterm birth were included as covariates in all models, but their corresponding estimates are not reported above

Overall, Black mothers had heightened odds of all adverse outcomes, with odds ranging anywhere from 1.16 to 2.72 times higher than odds for White mothers. Latina mothers, too, saw elevated odds for certain outcomes such as preterm birth (OR = 1.11) and very low birthweight (OR = 1.23) relative to White mothers. There is also significant interaction between midwife and Black maternal race/ethnicity for all outcomes, and significant interaction between midwife and Latina maternal race/ethnicity for preterm birth.

While the significance or non-significance of the interaction parameters are useful in testing whether the effect of midwife differs by maternal race, the estimates themselves are not as useful and prove difficult to extend to real-world context. For clarity, I will provide some sample interpretations of the coefficients. For instance, in the preterm birth model, midwife attendant has a coefficient of -0.386. As shown in Table 4b, this corresponds to an odds ratio of $e^{-0.386}$=0.681. That is, the odds of preterm birth for White mothers with midwives is 0.681 times the odds of preterm birth for White births attended by physicians. Black maternal race has a coefficient of 0.413, which indicates that the odds of preterm birth for Black mothers attended by physicians is $e^{0.413}$ = 1.51 times the odds of preterm birth for White mothers attended by physicians, ceteris paribus. The midwife and Black maternal race interaction term has a coefficient of 0.107. This tells us that the odds of preterm birth for Black mothers with midwives is $e^{-0.386+0.413+0.107}$ = 1.14 times the odds of preterm birth for White mothers attended by physicians, all else equal. The interaction term represents the effect of midwives on top of the baseline midwife effect of -0.386. In this example case of preterm birth and Black mothers, we see that while midwife attendance attenuates some of Black mothers' elevated risk relative to White mothers, disparities still persist.

To better aid interpretation, Figure 2 on the following page displays the predicted probabilities of each birth outcome by birth attendant, stratified by maternal race/ethnicity.

Figure 2. Marginal effects of midwife on probability of outcomes, by maternal race



Visually, one can see the slopes in many of these marginal effect plots vary by maternal race/ethnicity. For instance, midwife attendance results in a much steeper decrease in probability of low Apgar score and very low birth weight for Black mothers relative to White mothers. Relating these observations to the estimates presented in Table 4, it appears that some of this difference is indeed driven by effects of maternal race and its interaction with midwife, but may also be attributed to other covariates that are differentially distributed by race and hence additionally affecting the predicted probabilities displayed.

Multilevel model

After accounting for state-level clustering in birthweight as well as the state-level effect of MISS score quartiles, midwife-attended births are found to be on average 67.6 grams heavier than physician-attended births (Table 5). Notably, after incorporating these state-level effects, the interactions between midwife and Black/Latina mothers are no longer statistically significant terms. However, MISS score quartile has a slightly significant effect on birthweight, with a one unit change in score quartile corresponding to a 3.8 gram increase in birthweight. That is, all else held equal, birthweights in states with more supportive midwifery policy tend to be higher than those in states with more restrictive policies in place. Notably, there is a significant amount of state-level variation in the effect of MISS score quartile, which may warrant further study.

Table 5. Multilevel model estimates

Variable	**Birthweight (grams)**
Midwife	67.57** (6.58)
Maternal race: Black	-223.58** (8.41)
Maternal race: Latinx	-20.82* (8.09)
Midwife*Black	9.70 (16.66)
Midwife*Latinx	6.36 (8.09)
MISS score quartile	3.75* (1.37)

Random effect parameter	**Variance**
Intercept	705.20**
MISS score quartile	69.97**

***signifies p<0.05, ** signifies p<0.01**

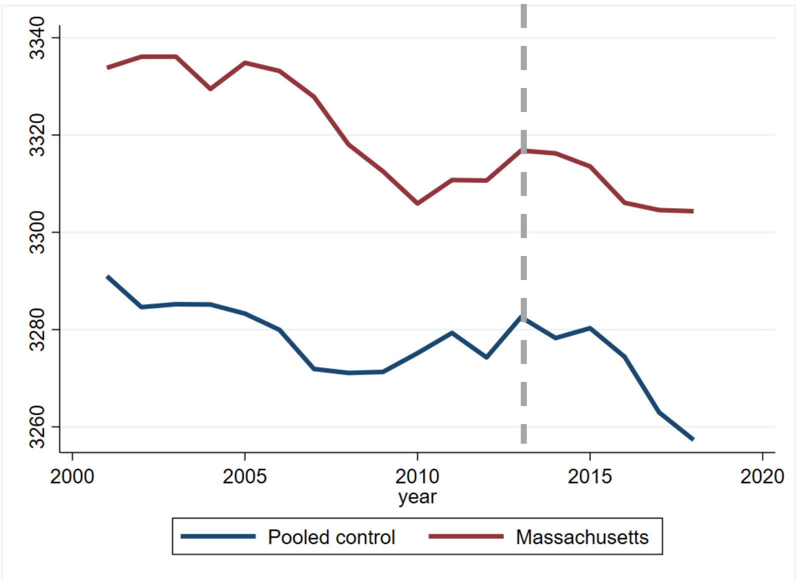
Note: maternal age, education, marital status, insurance type, WIC receipt, BMI, weight, smoking status, prenatal care start time, county population, birth facility, pregnancy weight gain, previous cesarean procedure, and previous preterm birth were included as covariates in all models, but their corresponding estimates are not reported above

The midwife and maternal race/ethnicity interaction terms are no longer significant in this model, suggesting that accounting for state-level heterogeneity in the dataset explains most of the differential effect of birth attendant on birthweight by maternal race/ethnicity. However, the main effects of maternal race/ethnicity remain significant, indicating that aside from between-state variation, there is significant within-state variation of birthweight by maternal race. Specifically, Black and Latina mothers have lower birthweights than White mothers in the same state, even after controlling for key covariates. Overall, midwifery policy appears to have a significant effect on birthweights, though its effect size is not nearly as large as the effects of variables that act at the more case-specific, within-state level such as birth attendant or maternal race/ethnicity.

Case Study

Table 6 summarizes findings from the difference-in-differences regression comparing trends in mean birthweight in Massachusetts to those in a pooled group of control states. Figure 3, below, displays the raw birthweight trends year by year. A visual comparison shows the parallel trends assumption to roughly hold between Massachusetts and the pooled control group.

Figure 3. Birthweight trends in Massachusetts vs. pooled control, 2000-2018



The pooled control was created from birth cases from a subset of states in the NVSS data in which policies delineating midwifery practice models did not change over this time frame: Alaska, Colorado, DC, Hawaii, Maine, Michigan, Minnesota, Nevada, Washington, and West Virginia (Pearson, 2001). The use of a synthetic control group was also briefly considered. However, the nature of the synthetic control approach makes it difficult to estimate the treatment effect when the synthetic control does not closely match the treatment group, so I only include the outputs in the Appendix, Figure A4, as a reference. Though the synthetic controls were not perfect matches, they help illustrate how post-policy trends in birthweights in Massachusetts appear to deviate from expected trends, even relative to controls constructed under different methodologies.

After controlling for state-level covariates of average maternal age, percent White/Black/Latina mothers, percent male births, percent singleton births, and average maternal education level, the estimated difference-in-differences treatment effect was approximately 8.12 grams. That is, controlling for the aforementioned covariates and assuming that the pooled states' birthweight trend represents the counterfactual trend for Massachusetts, the model estimates the policy to be associated with an 8.12 gram increase in birthweights for Massachusetts. Though this effect was not significant at the 0.05 level, it is approaching significance, with a p-value of 0.079.

Table 6. Difference-in-difference regression results

	Birthweight	**p**	**White BW**	**p**	**Black BW**	**p**	**Latina BW**	**p**
MA	67.57** (6.58)	0.007	20.48** (5.59)	0.001	115.89** (4.03)	0.000	-48.53** (4.48)	0.000
Post	-34.04** (5.47)	0.000	-0.10** (6.85)	0.988	-3.32** (4.93)	0.505	-16.42* (5.49)	0.000
MA*Post	8.12 (4.63)	0.079	-2.12 (9.69)	0.828	13.07 (6.97)	0.070	10.97 (7.76)	0.167

Note: controlling for average maternal age, % Black/White/Latina mothers, % male births, multiplets, and average maternal education level at the state-level

Sub-analyses for average birthweights by maternal race/ethnicity show the policy change to also be associated with an increase in mean birthweight specifically among Black and Latina mothers. Though again, these effects are not significant at the 0.05 level, they too are approaching significance. Interestingly, the policy was not associated with as large an impact on births to White mothers, with an effect of approximately -2.12 grams at p=0.828. In all, though concrete conclusions cannot be drawn, there is some evidence that switching to an autonomous midwifery practice framework may have been associated with a rise in birthweights in Massachusetts, both overall and among Black and Latina mothers in particular.

VII. DISCUSSION

In this paper, I sought to compare birth outcomes by birth attendant type, determine whether birth attendant type was equally consequential for White, Black, and Latina mothers, and examine the role of state-level policy on the relationships between birth attendant and outcomes. Raw bivariate analysis yielded directions and magnitudes of association between birth attendant and outcomes that are in concordance with the findings of previous studies. Notably, even after taking a novel approach and inverse probability weighting the data, these directions of association were still robust. Logistic regressions indicate that midwife attendance is associated with significantly lower odds of experiencing preterm birth, low or very low birthweight, low Apgar score, or cesarean section, and significantly higher odds of vaginal birth after cesarean, even after controlling for confounders and known risk factors. These findings have strong implications for the role of midwives in healthcare, as they establish that midwife-attendance not only yields better outcomes, but also reduce rates of cesareans and repeat cesareans, which are costly and undesirable interventions.

VII. DISCUSSION

When midwife and maternal race/ethnicity interaction effects were incorporated into regression models, the main effect of midwife on birth outcomes remained consistent. However, I found that the effect of midwife was significantly different for Black mothers relative to White mothers, for all outcomes. The effect of midwife on preterm birth was also significantly different for Latina mothers relative to White. Overall, while midwives are associated with lower odds of adverse outcomes across the board, they appear to be particularly protective for Black mothers in many cases. While I controlled for factors such as education level, insurance type, prenatal care duration, smoking status, and WIC receipt, it remains difficult to say whether the effects observed are strictly due to maternal race, or if they can be explained by other factors that are correlated with race but not captured in the NVSS data.

While theoretical frameworks and previous work offer viable explanations for why midwives may be particularly consequential for Black mothers, there remain many opportunities for further study. Perhaps midwifery-led care is especially protective for Black mothers because it represents a safer alternative to the physician-led, hospital-based care that currently disproportionately harms mothers of color. Another explanation might be that births to Black mothers attended by midwives are fundamentally different than those attended by physicians, in ways not entirely accounted for in my methodology. Potential areas of further study include the effect of having a birth attendant of the same racial/ethnic identity, the effect of maternal nativity (i.e. immigrant or US-born), or how the effect of midwife attendant may vary by credential type or birth facility.

Results from my multilevel analysis suggest that states with more integrative midwifery policies in place have higher mean birthweights than states with less integrative policies, even after controlling for observable confounders of birthweight. My findings align with previous literature that link policies that mitigate the effects of socioeconomic deprivation with improved birth outcomes (Pearlman & Robinson, 2022). It may be the case that a states' MISS score is correlated with other state-level measures such as political attitudes or average household income, and it is worth considering incorporating these relevant state-level covariates in future analyses. Calculation of the intraclass correlation indicates that only 0.16% of the unexplained variation in birthweights occurs at the state level in my model. The large amount of heterogeneity in the effect of MISS score quartile by state merits further study and finer area-level analyses. Here, I control for county population, but lack comprehensive information about distance to nearest provider and other geospatial factors that likely play a key role in determining birth attendant and birth outcomes. Knowing how critical area-level contexts are for healthcare access, it may be worth linking birth outcomes data to county-level data such as the density of practicing midwives, community resources, or other helpful contextual information.

The case study corroborates my findings from the multilevel regression, in that the difference-in-differences regressions suggest Massachusetts's shift towards an independent midwifery practice model was associated with an increase in birthweight (p=0.079). Sub-analyses showed that point estimates of effects on mean birthweights among Black and Latina mothers were positive, but not significant (p=0.07 and 0.167). Nonetheless, these slight increases in birthweight may reflect the effect of mothers' improved access to CNM services in Massachusetts, as well as midwives' growing opportunities to practice and care for mothers on their own, independent of a medicalized framework. Recognizing that there may be time-lagged effects of such a policy change, such as a gradual influx of midwives moving to or applying for a license in Massachusetts, incorporating additional years of post-policy data (once available) and conducting repeat analyses might help strengthen these results.

While of course there are countless upstream factors that contribute to adverse birth outcomes and disparities beyond those that I have acknowledged here, this study offers a glimpse into actionable steps that can be taken within the realm of healthcare policy to improve MCH. There remains much work to be done, but my findings are a promising first step towards dissecting out the true causal effects of birth attendant and midwifery policy on not only birth outcomes, but also racial disparities in MCH.

VIII. CONCLUSIONS AND POLICY RECOMMENDATIONS

While the US spends nearly $4 trillion on health care each year, we consistently rank last in measures of maternal and infant health among developed nations. Pregnancy and childbirth are arguably over-medicalized in America, despite limited evidence that medical interventions provide better outcomes for mother and baby. National rates of caesarean sections and other adverse birth outcomes are exceptionally high, a burden that disproportionately falls on mothers of color. Black women are three times more likely, and Native American women more than twice as likely to die of pregnancy-related causes than White women in the US (CDC, 2019). Latinx and Asian and Pacific Islander mothers also lag far behind White mothers in maternal and infant health metrics.

Midwifery care has been pushed into the limelight as a potential strategy to address the challenges and disparities in MCH that our nation faces. For example, the Black Maternal Health Momnibus Act of 2021 recently introduced to Congress aims to diversify the perinatal workforce, in part by providing better funding and support for midwives. The Department of Health and Human Services' action plan to reduce maternal mortality and morbidity also features explicit calls to better integrate midwifery in state Medicaid programs. Due to the complex and patchwork landscape of midwifery in the US, it was difficult to point to explicit mechanisms in previous (largely associative) studies.

The applications of quasi-experimental approaches in my work sifted out treatment selection bias and other potential confounders, allowing me to get a few steps closer to elucidating the nature and directions of these complex relationships using national data. I find midwives to be associated with better birth outcomes for all mothers, but especially protective for Black mothers for certain outcomes. Moreover, I link policies that are more compatible with the integration of midwives into health care with higher mean birthweights at the state-level, adding to the growing evidence base in favor of reproductive healthcare policy reform. In all, this study answers lingering questions about midwifery as a potential means to advance MCH. From my findings, I set forth the following policy recommendations:

1. Standardize licensure for CPMs in all states.

The US does not currently have a universal license to practice for midwives. Credentialing remains inconsistent from state to state. At the time of writing, Certified Professional Midwives only have legal recognition and a path to licensure in 36 states and the District of Columbia, with Illinois being the latest state to set standardized education and licensing criteria for CPMs. For people giving birth, this means that access to certain midwifery services varies greatly depending on location. For individuals training to be midwives, these laws (or lack thereof) limit them geographically and even criminalize their work. Just a few years ago in New York State, Elizabeth Catlin, a CPM-licensed midwife, was arrested and charged with 95 felony counts for delivering babies in Yates County, since the state does not recognize the CPM credential (Pager, 2019). Yates County is home to hundreds of Mennonite families, the majority of which do not drive cars or have health insurance. On top of a scarcity of obstetricians and birth attendants in the region, many Mennonite mothers choose to avoid hospitals altogether and instead deliver their children at home. However, restrictive state policies mean that licensed midwives are few and far between outside of New York City. Catlin attended upwards of 70 of the 200-some Mennonite births each year, and though she helped safely deliver hundreds of babies and met a profound need in the community, she was arrested and charged with unauthorized practice of the profession, because New York requires midwives to hold at least a Master's degree.

After three years of prosecution, all charges against Catlin were dropped save for one count of unauthorized practice of a profession. However, exclusionary licensing rules still stand, meaning that CPMs can still be charged with the felony of practicing without a license in many states. However, there is a strong body of evidence that suggests that – at least for low-risk pregnancies – home births and births attended by midwives are just as safe as in-hospital births (Olsen & Clausen, 2012). Having CPMs licensed to practice and to legally work in out-of-hospital birth settings alongside backup medical services can reduce the rates of unnecessary intervention, increase access, and lower costs of care, ultimately bearing better outcomes for low-risk mothers.

2. Phase out supervision and collaborative practice agreements for CNMs.

Providing accessible health care while also protecting patient safety is a delicate balancing act. Physicians sometimes argue that safety may be compromised when CNMs practice without the oversight of a doctor, but this is not necessarily the case. Previous work has already demonstrated that women living in states with regulations that support autonomous CNM practice have far higher odds of having a CNM-attended birth, compared to states where CNMs are subject to collaborative practice agreements (Yang et al., 2016). Moreover, my results indicate that there is no evidence of midwife-attendance being more dangerous than physician-attendance. The demand for a practice agreement that must be signed off on by a physician implies that CNMs require constant supervision, which is a misguided and arguably damaging view.

What we do know is that the country is facing a shortage of maternity care providers that primarily burdens already vulnerable populations. Collaborative or supervisory practice agreement requirements all too easily restrict access to care and choice of provider for mothers, and often interfere with effective coordination of care. Having to operate under supervision often prevents CNMs from exercising their full scope of practice or receiving reimbursements for services that fall well within the realm of what they are trained and licensed to do. Such requirements discourage individuals from entering the profession, and unnecessarily encumber physicians and midwives alike. Physicians have little incentive to sign these agreements, while CNMs are left unable to practice when physicians are not willing to take them in. A more useful model might be a graduated training model, in which CNMs are only required to work under the supervision of more senior CNMs or practitioners for their first 2,000 hours of practice; such a model has proven successful for transitioning newly licensed nurse practitioners into the workforce in several states.

3. Promote equitable inclusion and reimbursement of midwifery care in Medicaid plans.

While Medicaid covers more than 40% of births in the US, not all care providers are reimbursed equally. Birth centers often have trouble contracting with Medicaid-managed care organizations, and consistently face low reimbursement rates even after entering these contracts. Under the fee-for-service model, too, reimbursements for birth centers remain far below what obstetricians and hospitals receive. These conditions make it difficult for many birth centers to provide care, with some having to place limits on how many Medicaid beneficiaries they can serve.

CNM reimbursement rates under Medicaid also range from 70 to 100% of physician reimbursement rates, depending on the state. Only 29 states reimburse CNMs equally relative to their physician counterparts, and there is a steep gradient in terms of how much midwives receive in the remaining states. One study found that in 2015, Medicaid reimbursements for CNM/CMs for a normal vaginal delivery ranged tenfold across the nation, from $328 in New Jersey, to $3,258 in Montana (Baker et al, 2021). These policies disincentivize hospitals from hiring CNMs, and also may deter physicians from signing collaborative practice agreements that some CNMs need to even practice in hospital settings at all. Care options for mothers enrolled in Medicaid are consequently limited by these structural and financial barriers. In order for midwifery care to be financially sustainable while also being an accessible option for all mothers, state Medicaid agencies must improve their rates and reimbursement models.

4. Invest in training and diversifying the midwifery workforce.

To make midwifery more accessible to mothers that stand to benefit greatly from it, policy needs to be amenable to not just practicing midwives, but also individuals pursuing and training for the profession. There are currently 38 accredited midwifery education programs, of which 35 exist within schools of nursing. Moreover, these programs are only located in 22 states. The midwifery workforce remains disproportionately White, but research has demonstrated the importance of cultural congruency and having a workforce that reflects the people it serves. Only 5.8% of CNMs and CMs who recertified with the American Midwifery Certification Board identify as people of color (Wren Serbin & Donnelly, 2016). While this number rises to 14.5% among those certifying for the first time, continual efforts must be made to ensure that the racial makeup of midwifery providers evolves to reflect the diverse communities that they serve.

Beyond education, systems and training programs should be structured to provide more opportunities for those enrolled in midwifery education programs to shadow other maternity care providers. Whether in hospitals, freestanding birth practices, or midwifery practices, this is a crucial step to better integrate midwives into maternity health care teams. The US is facing a shortage in maternity care providers, and while the promotion of a robust and diverse midwifery workforce can help fill these alarming gaps, we must also have the requisite supports in place to graduate trainees into healthcare settings that can accommodate them.

Conclusions

My research reinforces the fact that midwifery represents a safe, high-quality, and low-cost alternative to traditional physician-led approaches to pregnancy and childbirth. Trained midwives are equipped to provide safe, holistic, and culturally congruent care that keeps low-risk mothers low-risk. Yet, myriad policy barriers exist that prevent them from fully integrating into our healthcare system, and these hostile policies are now demonstrably linked to poorer outcomes and lower birthweights overall. Our current model of obstetric care was largely built on racist, classist, and elitist grounds, and continues to actively harm vulnerable mothers today. With the midwifery model offering holistic care that prioritizes shared decision-making, avoids unnecessary interventions, and places mothers in control of the process, many mothers and infants stand to benefit from the ability to choose between midwife-led and physician-led care.

While a growing number of mothers are interested in midwifery care, access is strongly constrained by geographic and socioeconomic factors. Eliminating these barriers will require a combination of structural healthcare policy reforms, and more targeted efforts to expand the workforce and amend attitudes towards midwifery in medicine. Licensure and practice laws, as well as healthcare financing, should be reformed and standardized to be more compatible with midwives and midwifery care – this would make it easier for mothers seeking such care to find and utilize it. Just as importantly, we need to continue investing in the expansion and diversification of the midwifery workforce, training midwives that can practice both in community-based and hospital settings.

In my analysis, I sought to balance out risk profiles to account for selection bias by birth attendant and isolate the effect of midwives from confounding factors. My results suggest that, given two identical populations of mothers that differ only by birth attendant, those whose births are attended by midwives will be less likely to experience adverse birth outcomes. These findings offer valuable insights regarding the comparative efficacy of birth attendants. Yet in the real world, one can argue selection bias by birth attendant is, to some degree, irrelevant, as is the evidence that midwives see better outcomes than physicians. Even if mothers seeking midwifery care were fundamentally different than mothers seeking physician-led care; even if midwives' outcomes were only comparable to and not better than physicians' outcomes, the midwifery model of care would still represent a safe, viable, and cost-saving alternative for those mothers who seek it.

I do not assert that midwifery care is a one-size-fits-all solution. What is true, though, is that midwife-led care is a viable option for a large portion of birthing people but remains largely inaccessible across the country. What is important going forward, then, is that an individual's choice of care provider is not determined by their location or ability to pay, and that qualified practitioners' capacity to offer such care is not unnecessarily hampered by inconsistent state laws.

IX. APPENDIX

Table A1. MISS Scoring Criteria (Vedam et al., 2018)

OPTIONS FOR BIRTH SITE

- Do CPMs offer planned home birth services? 0=No or under legal duress; 1=Yes
- Do CNMs offer planned home birth services? 0=No; 1=Yes
- Do CMs offer planned home birth services? 0=No; 1=Yes
- Do MDs offer planned home birth services? 0=No; 1=Yes
- Do other care providers (e.g. Licensed midwife, Naturopathic Doctor, Doctor of Osteopathy, etc.) offer planned home birth services? 0=No; 1=Yes
- Do CPMs offer birth center services? 0=No; 1=Yes
- Do CNMs offer birth center services? 0=No; 1=Yes
- Do CMs offer birth center services? 0=No; 1=Yes
- Do MDs offer birth center services? 0=No; 1=Yes
- Do other care providers (e.g. Licensed midwife, Naturopathic Doctor, Doctor of Osteopathy, etc.) offer birth center services? 0=No; 1=Yes
- Are there statutory limitations or restrictions to site of practice for CNMs? 0=Yes; 1=Lack of Access to Hospital Privileging or Physician Consultation/Referral/Signer ; 2=No
- Are there statutory limitations or restrictions to site of practice for licensed CPMs? 0=Yes; 1=Lack of Access to Hospital Privileging or Physician Consultation/Referral/Signer; 2=No
- Are there statutory limitations or restrictions to site of practice for licensed CMs? 0=Yes; 1=Lack of Access to Hospital Privileging or Physician /Consultation/Referral/Signer; 2=No
- Are there statutory limitations or restrictions to site of practice for MDs? 0=Yes; 1=limits access to hospital privileges if attends home births, 2=No
- Does state have evidence-informed, validated QA/QI state system for all sites (home, hospital, birth centers) ? 0= Hospital only; 1 = Hospital and birth center only; 4 = Home/hospital/ birth center
- Are there statewide systems for smooth transfer across birth sites ? 0=No, 3=Yes

REPORTING AND DATA COLLECTION

- Does the birth certificate in the state record planned place of birth as well as actual place of birth? 0=No; 1=Yes

VBAC

- Is VBAC allowed for licensed midwives ? 0=Prohibited or unregulated state; 1=allowed only by restrictive conditions (eg physician approval); 2=allowed by meeting certain conditions and with informed consent; 3=unrestricted

CERTIFIED PROFESSIONAL MIDWIVES (CPM)

Regulation & Medicaid

- Is direct-entry midwifery regulated ? 0=Prohibited; 1=Allowed by previous judicial opinion/ or not mentioned/not prosecuted to date; 2=Unregulated but allowed by statutory permission; 4=Licensed
- Is CPM credential sufficient for licensure (additional steps for licensure may be required: TB test, state application requirements, state examination, etc.)? 0 = No; 1 = Yes
- Is Medicaid reimbursement available ? 0 = No; 2 = Yes, but challenges being reimbursed; 3=Yes

Autonomous Practice & Risk Assessment

- Is physician supervision or outside assessment required? 0=Yes; 1=No
- Is a consultation agreement/collaborative practice agreement with physician required? 0=Yes, formal written agreement/or formal consultation req'd/or unregulated; 1=Yes, but informal & unwritten; 3=No agreement req'd
- Is consultation/referral required (instead of recommended) by law for certain conditions? 0 = Unregulated state; 1=Required but difficult to access when needed; 2=Not required but difficult to access when initiated by CPM; 3=Required or not required but easily accessed when initiated by CPM

Scope of Practice

- Is scope of practice limited by law to childbearing year? 0 = Yes; 1 = No
- Does scope of practice include well-woman care? 0 = No; 1 = Yes

Medications - Authority of Midwife to Obtain and Administer Medications

- What level of prescription-writing authority do CPMs have ? 0= Prohibited or not authorized; 1=Allowed only by physician prescription; 2= Limited list of medications allowed (routine and emergency medications, e.g. newborn antibiotic eye ointment, anti-hemorrhagic drugs); 3= Comprehensive list of medications given (specialized care medications - may require training, e.g. GBS prophylactic antibiotics, Pitocin), 4 = Full prescription-writing authority
- Do CPMs experience any challenges accessing any of the listed medications they are authorized to obtain and administer? 1= No; 0=Yes

Regulatory Board/Council/Advisory Committee

- Is midwifery representation on Board/Council/Advisory group required? 0 = No; 1 = CPM not specified; 2 = Yes

CERTIFIED NURSE MIDWIVES (CNM)

Regulation & Medicaid

- Are CNMs regulated ? 1=No; 4=Yes
- Is CNM credential sufficient for licensure (additional steps for licensure may be required: TB test, state application requirements, state examination, etc.)? 0 = No; 1 = Yes
- Is Medicaid reimbursement available ? 0 = No; 2 = Yes, but challenges with reimbursement including birth site; 3= Yes

Autonomous Practice & Risk Assessment

- Is physician supervision for practice required? 0=Yes; 1=No
- Is a consultation agreement/collaborative practice agreement with physician required? 0=Yes,formal written agreement/or formal consultation req'd/or unregulated; 1=Yes, but informal & unwritten; 3=No agreement req'd
- Is consultation/referral required (instead of recommended) by law for certain conditions? 0 = Unregulated state; 1=Required but difficult to access when needed; 2=Not required but difficult to access when initiated by CNM for home and birth center; 3= Not required and easily accessed when initiated by CNM

Scope of Practice

- Is scope of practice limited by law to childbearing year? 0=Yes; 1=No
- Does scope of practice include well-woman care? 0 = No; 1 = Yes

Medications - Authority of Midwife to Obtain and Administer Medications

- Do CNMs experience any challenges accessing any of the listed medications they are authorized to obtain and administer? 1= No; 0=Yes
- What level of prescription-writing authority do CNMs have? 0= Prohibited or not authorized; 1=Allowed only by physician prescription; 2= Limited list of medications allowed (routine and emergency medications, e.g. newborn antibiotic eye ointment, anti-hemorrhagic drugs); 3= Comprehensive list of medications given (specialized care medications - may require training, e.g. GBS prophylactic antibiotics, Pitocin), 4 = Full prescription-writing authority

Regulatory Board/Council/Advisory Committee

- Is midwifery representation on Board/Council/Advisory group required? 0=No; 1=APRN mentioned; CNM not specified; 2=Yes

CERTIFIED MIDWIVES (CM)

Regulation & Medicaid

- Are CMs regulated ? 1=No; 4=Yes
- Is CM credential sufficient for licensure (additional steps for licensure may be required: TB test,state application requirements, state examination, etc.)? 0 = No; 1 = Yes
- Is Medicaid reimbursement available ? 0 = No; 1 = Yes, but challenges with reimbursement including birth site; 3= Yes

Autonomous Practice & Risk Assessment

- Is consultation/referral required (instead of recommended) by law for certain conditions? 0 = Unregulated state; 1=Required but difficult to access when needed; 2=Not required but difficult to access when initiated by CM for home and birth center; 3= Not required and easily accessed when initiated by CM
- Is physician supervision required? 0=Yes; 1=No
- Is a consultation agreement/collaborative practice agreement with a physician required? 0=Yes, formal written agreement/or formal consultation req'd/or unregulated; 1=Yes,but informal & unwritten; 3=No agreement req'd

Scope of Practice

- Limited by law to childbearing year? 0 =Yes ; 1 = No
- Scope of practice includes well-woman care? 0 = No; 1 = Yes

Medications - Authority of Midwife to Obtain and Administer Medications

- What level of prescription-writing authority do CMs have ? 0= Prohibited or not authorized; 1=Allowed only by physician prescription; 2= Limited list of medications allowed (routine and emergency medications, e.g. newborn antibiotic eye ointment, anti-hemorrhagic drugs); 3= Comprehensive list of medications given (specialized care medications - may require training, e.g. GBS prophylactic antibiotics, Pitocin), 4 = Full prescription-writing authority

Regulatory Board/Council/Advisory Committee

- Is midwifery representation on Board/Council/Advisory group required? 0 = No; 1 = CM not specified; 2=Yes

Figure A1. Distribution of MISS scores, 2014-15

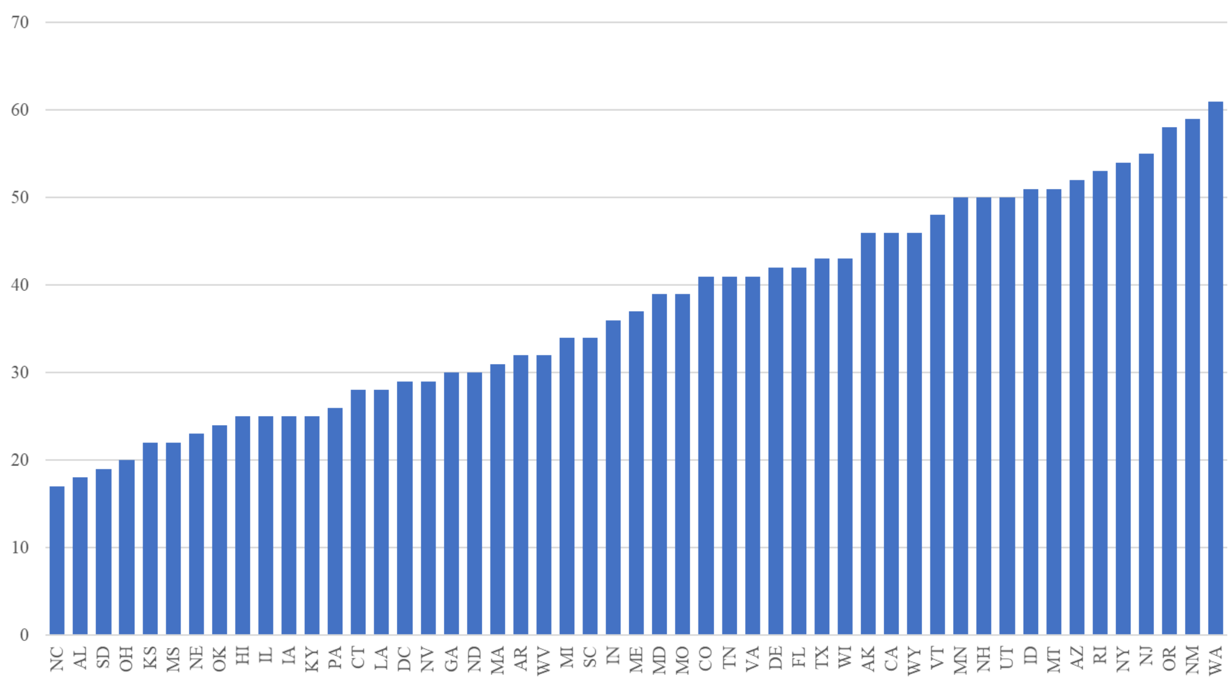


Table A2. Unweighted summary statistics, by birth attendant

	Total (n=2,593,795)	Physician (n=2,337,666)	Midwife (n=256,129)	Test statistic
	Mean/%			t or χ^2
Age	27.8	27.9***	27.8***	-9.66
Race		***	***	19.13
White	59.6	59.0	65.5	
Black	14.6	14.9	11.6	
Hispanic	25.8	26.1	22.9	
Education		***	***	372.39
< HS	15.5	15.5	15.6	
HS grad	47.7	47.9	45.3	
College	26.7	26.5	28.3	
Grad school	10.2	10.1	10.8	
Facility		***	***	182.16
Hospital	98.7	99.96	86.82	
Birth Center	0.56	0.02	5.5	
Home (intended)	0.69	0.01	6.9	
Home (unintended)	0.02	0.0	0.71	
Prenatal care start		***	***	29.74
none	1.4	1.4	0.8	
1-3 month	76.9	77.1	74.7	
4-6 month	17.5	17.3	19.7	
7 to final month	4.3	4.2	4.8	
County population		***	***	307.11
<10k	1.2	1.2	0.73	
10-25k	4.4	4.5	3.5	
25-50k	7.3	7.3	7.0	
50-100k	8.9	8.8	9.4	
100-250k	16.1	15.8	18.6	
250-500k	15.1	14.9	16.1	
500k-1m	18.7	18.5	20.1	
>1m	28.4	28.9	24.6	
BMI	26.2	26.3***	25.4***	-69.94
Eversmoke	8.8	8.9***	7.5***	117.68
Pre-pregnancy weight	153.9	154.3***	150.0***	-54.09
Married	58.3	57.7***	63.6***	83.35
Medicaid	44.9	45.5***	39.6***	151.57
Private insurance	47.3	47.5***	45.5***	256.08
WIC	44.5	44.9***	40.8***	181.10
Previous cesarean	14.5	15.8***	2.6***	132.03
Previous preterm birth	2.5	2.6***	2.1***	59.37
Birthweight	3335.1	3325.5***	3422.3***	87.48
Preterm birth	15.9	16.5***	11.3***	8212.89
Low birthweight	5.1	5.4***	2.6***	9671.06
Very low birthweight	0.8	0.83***	0.1***	5996.75
Low Apgar score	3.4	3.48***	2.65***	1755.39
Cesarean	29.1	32.11***	1.13***	37710
VBAC	1.7	1.63***	2.4***	12100

*signifies p<0.05, ** signifies p<0.01, *** signifies p<0.001

Note: t-tests used for continuous variables, chi-square tests used for categorical variables

Table A3. Weighted summary statistics, by birth attendant

	Total (n=2,593,795)	Physician (n=2,337,666)	Midwife (n=256,129)	Test statistic
	Mean/%			t or χ^2
Age	27.85	27.83	27.88	1.11
Race				1.79
White	59.6	59.5	59.7	
Black	14.7	14.7	14.7	
Hispanic	25.7	25.8	25.6	
Education		***	***	24.25
< HS	15.7	15.9	15.5	
HS grad	47.2	47.6	46.9	
College	26.7	26.4	27.0	
Grad school	10.3	10.1	10.6	
Facility		**	**	5.92
Hospital	98.6	98.5	98.7	
Birth Center	0.6	0.69	0.56	
Home (intended)	0.5	0.3	0.7	
Home (unintended)	0.2	0.4	0.007	
Prenatal care start				1.60
none	1.4	1.4	1.4	
1-3 month	76.7	76.7	76.5	
4-6 month	17.6	17.7	17.6	
7 to final month	4.4	4.4	4.4	
County population		***	***	20.55
<10k	0.9	1.1	1.1	
10-25k	4.0	4.4	4.3	
25-50k	7.2	7.3	7.1	
50-100k	9.3	9.0	8.6	
100-250k	16.4	16.2	16.0	
250-500k	14.7	14.9	15.1	
500k-1m	18.8	18.6	18.9	
>1m	28.6	28.5	28.9	
BMI	26.1	26.2**	26.0**	-8.88
Eversmoke	8.7	8.9***	8.5***	23.92
Pre-pregnancy weight	153.6	153.9**	153**	-7.95
Married	58.4	58.2***	58.7***	16.82
Medicaid	44.5	44.9***	44.2***	30.25
Private insurance	47.6	47.1***	48.1***	51.24
WIC	44.2	44.6***	43.8***	36.68
Previous cesarean	14.2	14.5**	14.0**	8.62
Previous preterm birth	2.6	2.6**	2.7**	7.930
Birthweight	3361.1	3325.8***	3396.5***	50.91
Preterm birth	14.4	16.4***	12.4***	1442.08
Low birthweight	4.2	5.4***	2.9***	1432.34
Very low birthweight	0.48	0.81***	0.15***	387.61
Low apgar score	3.0	3.5***	2.6***	297.92
Cesarean	16.7	30.8***	2.4***	18100
VBAC	7.0	1.5***	12.5***	29900

*signifies p<0.05, ** signifies p<0.01, *** signifies p<0.001

Note: t-tests used for continuous variables, chi-square tests used for categorical variables

Figure A2. Quantile-quantile plot of random state-level effects of MISS quartile

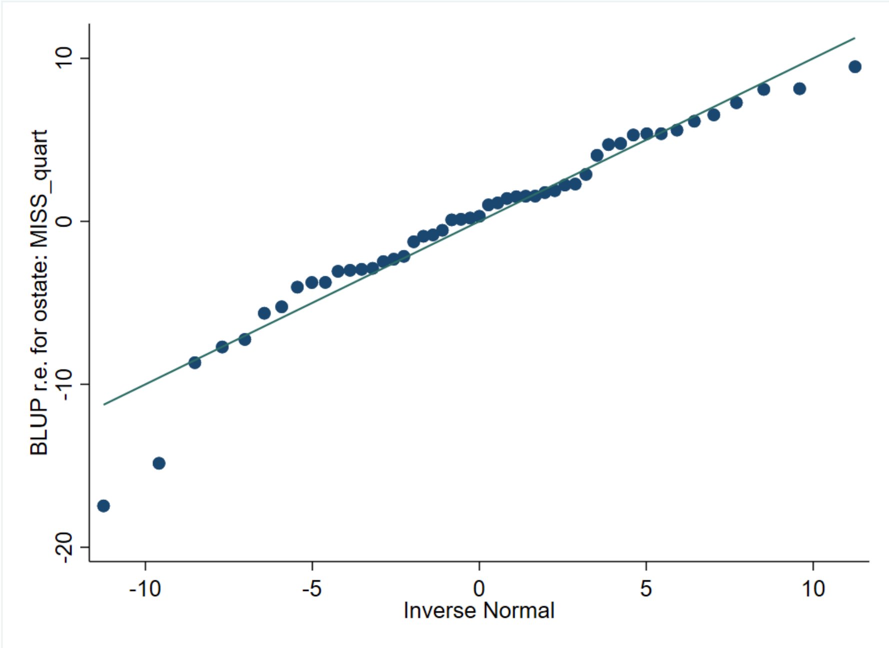


Figure A3. Histogram of random state-level effects of MISS quartile

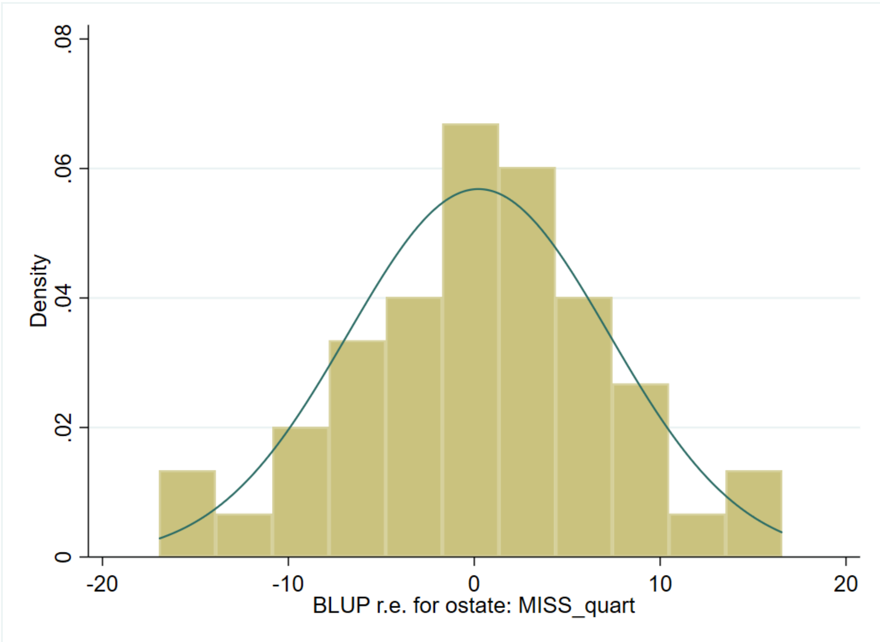
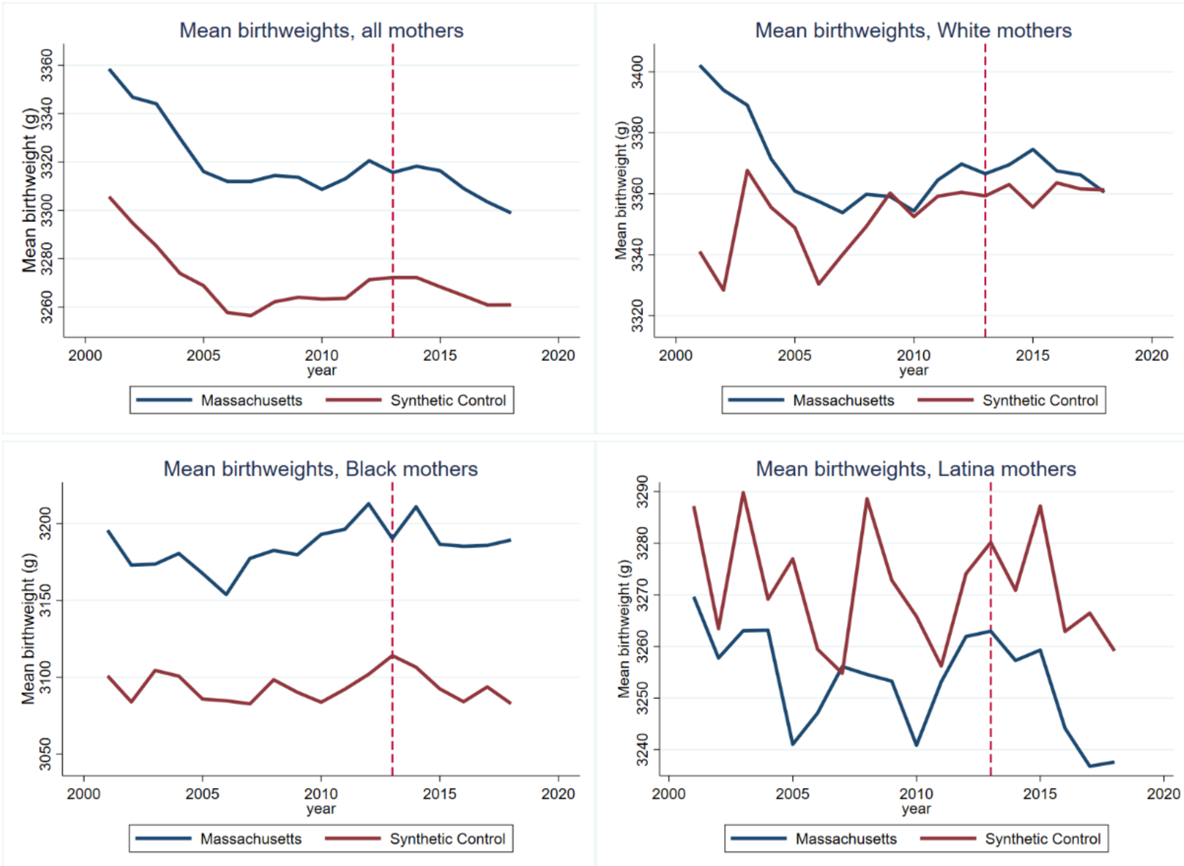


Figure A4. Synthetic control results



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