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OCCUPATIONAL HAZARD?
AN ANALYSIS OF BIRTH OUTCOMES AMONG PHYSICIAN MOTHERS

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ABSTRACT

Training to become a physician involves long work hours that can be physically demanding, particularly for surgeons. Are birth outcomes of physician mothers affected as a result? Using Texas birth data from 2007-2014, we compared birth outcomes between physicians and another highly educated group, lawyers, and between surgeons and non-surgeon physicians. Further, using a difference-in-differences framework, we examine whether the Accreditation Council for Graduate Medical Education 2011 duty hour reform, which lowered trainee work hours, impacted the birth outcomes of babies born to physicians compared with lawyers. We find that physicians have lower birth weights and shorter pregnancies than lawyers with the results driven by physicians in surgical specialties. However, the duty hour reform appears to not have impacted birth outcomes. Thus, we find that physicians tend to have worse birth outcomes than lawyers and, in this case, the work reform did little to address the difference.

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1 Introduction

Working in a high stress occupation may have a significant impact on one's health. For pregnant women in strenuous occupations, those negative impacts could extend to their children. For example, maternal stress has been linked to increased production of cortisol (Coussons-Read 2013, Kramer et al. 2009), a hormone that regulates the body's stress response, and epinephrine and norepinephrine (Katz et al. 1988), hormones associated with the body's fight-or-flight response. Both sets of hormones can hinder fetal growth if present in too high quantities. Further, maternal stress can impact fetal health through behavioral responses to stress including worse sleep, changes in diet, and a reduction in physical activity (Coussons-Read 2013).

One occupation that is particularly stressful, physically demanding, and involves long work hours during child-bearing years is medicine, particularly surgery. For example, physicians in specialties such as internal medicine, family medicine, and surgical subspecialties routinely work up to 80 hours per week during inpatient portions of training. In a 2023 study on surgical residents, Gates et al. (2023) found that surgical residents reported a median 78 total patient care hours per week. As the share of physicians that are women has steadily increased (**Figure 1A**) it is unknown if birth outcomes of physician mothers, in particular surgeon mothers, are affected as a result of their physically demanding occupation.

To study the potential impact of stressful occupations on birth outcomes, we compared birth outcomes between physicians and another highly educated group, lawyers, and between surgeon and non-surgeon physicians. While comparably educated people tend to initially sort into these occupations, the work of physicians, particularly those in training, tends to be more physically demanding, involving long hours, with many of those hours on one's feet. Comparing

physicians to lawyers allows us to study the association of a physically strenuous occupation on the birth outcomes of comparably educated mothers in those occupations.

In part recognizing the strenuous physical requirements of becoming a physician, the Accreditation Council for Graduate Medical Education (ACGME), the organization responsible for accrediting all graduate medical programs in the U.S., instituted several duty hour reforms that lowered work hours during the period of graduate medical education known as residency. Residency is the period of training after medical school in which physicians work intensively in their chosen specialty. Following a successful 2003 reform, which lowered the number of hours that residents could work weekly to 80 hours, the ACGME instituted a 2011 duty hour reform which limited the number of consecutive hours a first-year resident could work to 16 hours (Riebschleger & Nasca 2011). This was reversed in 2014 with duty hour reforms allowing first-year residents to work 24 hours continuously with 4 additional hours permissible for transitioning care and formal teaching, for a total of 28 hours (Burchiel et al. 2017). We add to the body of research that has studied the impact on medical practice of these various reforms (Volpp et al. 2007, Jena, Prasad, & Romely 2014, Wasserman 2023, Awan et al. 2021, Patel et al. 2014) by examining whether the 2011 ACGME reform impacted the birth outcomes of physician mothers by reducing work hours for those in training.

Using Texas birth records from 2007 to 2014 we compare the birth outcomes of physicians (birth weight, pregnancy length, and rates of pre-term birth, cesarean, and newborn abnormal conditions) to birth outcomes of lawyers, accounting for maternal characteristics such as age, prenatal visits, race, ethnicity, and other risk factors. Among physicians, we then estimate a similar model that compares birth outcomes of surgeons and non-surgeons, hypothesizing worse birth outcomes among surgeon mothers due to the particularly demanding nature of

surgical training, which involves longer work hours, more time on one's feet, and repeated instances of sexism from both colleagues and patients (Hutchinson 2020, Sudol et al. 2021, Lombarts & Verghese 2022). Finally, we estimate a difference-in-differences model to examine whether the 2011 ACGME duty hour reform impacted the birth outcomes of physicians (as compared to lawyers) and if there were heterogenous impacts on surgeons and non-surgeons, under the assumption that work hours of lawyers would not be affected by the medical reform and that work hours of surgeons were reduced by more than non-surgeon physicians.

We find that physicians have worse birth outcomes than lawyers. Specifically, after adjusting for several maternal characteristics, we find that physicians have 2.3% lower birth weights (75.84 grams) and 0.3% shorter pregnancies (0.12 weeks), both statistically significant at the 1% level. These findings are similar in magnitude to the estimated effects of air pollution on infant health identified in other studies (Currie & Walker 2011, Alexander & Schwandt 2022). We also find that physicians are 9.9% less likely to deliver via c-section. The estimated differences are driven primarily by physicians in surgical specialties. For example, when compared to non-surgeon physicians, we find that surgeons have 2.3% lower birth weights (71.56 grams), 0.9% shorter pregnancies (0.34 weeks), and are 32.4% more likely to deliver pre-term (0.045 percentage points). We find that the 2011 duty hour reform had no statistically significant impact on birth outcomes of physicians compared with lawyers or among physicians, surgeons compared with non-surgeons. However, from the upper bound on our estimate's confidence intervals, we are able to rule out with 95% confidence that the work reform would have completely closed the difference in birth outcomes between physicians and lawyers.

Several studies suggest that physicians tend to have better health behaviors than the general population (Frank & Segura 2009, Glanz et al. 1982). A majority of physicians report

that they are in excellent health or are satisfied with how they take care of themselves (Leuven et al. 2013, Ahmed et al. 2023). Given that physicians appear to be in better health in general, we would expect that physicians' birth outcomes would be better than those of comparably educated mothers. If so, our estimated difference in birth outcomes between physicians and lawyer mothers may understate any potential adverse impact of physician's work on birth outcomes.

Our study contributes to several strands of literature. First, our study adds to growing work on the impact of mothers' behaviors and environment during pregnancy on birth outcomes. Much of the economic literature around this issue seeks to provide support for the Fetal Origins Hypothesis, which argues that stress and other environmental factors that the mother experiences while pregnant can impact the health and long-term well-being of the child (Barker 1990, Almond & Currie 2011).

Our study also relates to literature that explores health care and behavior outcomes of physicians when they are patients. Because physicians are arguably highly informed about the benefits and costs of health care treatments, in theory their behavior and outcomes could differ greatly from that of the rest of the public. For example, physicians are less likely to undergo a cesarean when giving birth (Johnson & Rehavi 2016, Frakes et al. 2021) and are more likely to receive novel, targeted cancer drug therapy instead of surgery or radiation (Chen et al. forthcoming). This literature suggests that *ceteris paribus* physician mothers would be expected to have better birth outcomes than a comparably educated group of non-physician mothers. If so, our estimated difference in birth outcomes between physician and lawyer mothers may be biased downwards.

However, several studies find that despite their access to medical knowledge, physicians act similarly to the public. There is mixed evidence on physicians' adherence to care guidelines

with one study (Frakes et al. 2021) finding that physicians adhere to care guidelines at the same rate or only slightly more than non-physicians and another (Finkelstein et al. 2022) finding that physicians are far less likely to adhere to care guidelines. Despite agreeing professionally what the best care guidance is, the investments that physicians make in their own health may not be that different from otherwise comparable people.

Most directly related to our study Katz et al. (1988) identified that physicians were at an increased risk of adverse pregnancy outcomes including pre-term labor and intrauterine growth restriction. The effect appeared to be the strongest among residents. These results, however, were obtained through aggregating the results from studies that were conducted on small samples. Our paper builds on this finding by comparing birth outcomes of physicians to those of a similarly educated group, lawyers and among physicians, between surgeons and non-surgeons.

The paper is organized as follows. Section 2 provides background information on the Fetal Origins Hypothesis and the ACGME's prior duty hour reforms. Section 3 describes our data and Section 4 outlines our empirical methodology. Section 5 reports our results, which are discussed in Section 6. Section 7 concludes.

2 Background

2.1 Fetal Origins Hypothesis

The overall impact of in utero stressors on birth outcomes is well documented. Lauderdale (2006) finds that Arab women in California experienced a 34% increased risk of having a low birth weight infant in the six months after September 2001. The authors argue that the surge of anti-Arab sentiment after 9/11 led to an increase in maternal stress during pregnancy. In a similar study on maternal stress, Currie et. al (2023) estimate that mothers that were exposed to the Virginia beltway sniper, who perpetuated a series of random shootings around the

Washington D.C. metro area in October 2002, experienced a 25% increased likelihood of infant low birth weight and a 32% increase in the likelihood of a very premature birth. Almond and Mazumder (2011) find that Arab mothers exposed to Ramadan during pregnancy have lower birth weights likely due to fasting associated with Ramadan. Duncan et al. (2017) find that even short periods of maternal stress may impact birth outcomes with pregnant mothers who were exposed to a Super Bowl win of their home team experiencing a 4% increase in the likelihood of having a low birth weight child.

Several studies directly explore the role of a mother's work environment in pregnancy and birth outcomes. Using a measure of the strenuousness of work activities from the Census Occupational Classification System, Dave and Yang (2022) find that working in a relatively more strenuous job increases the likelihood of fetal macrosomia, a birth weight exceeding 4,000 grams, which is associated with maternal complications, but the likelihood of low birth weight, shorter gestational length, or pre-term birth are not affected. Similarly, Baum (2005) finds no adverse effect of working while pregnant on mother's birth outcomes and argues that any potential adverse impacts on birth outcomes that occur due to employment are offset by the increase in family income.

2.2 2003 Duty Hour Reform to Physician Training

In July 2003, the ACGME instituted the 2003 common duty hour reform, which limited the number of hours that residents could work to 80 hours per week (Philibert et al. 2002). Prior to this, residents would work on average 83 hours per week with residents in surgical specialties working anywhere from 102 to 110 hours per week, with many of these work hours accumulating in single stretches (Baldwin et al. 2003). After seeing the impact of several smaller work reforms and amid growing concern about the effects of sleep deprivation on patient

outcomes and physician well-being, the ACGME created a comprehensive set of rules governing the duty-hour standards for residents.

In the years since this first reform, there have been several studies that have sought to identify the impact of limiting duty hours on both patients and physicians. When looking at the short-term impact on patient outcomes, the reform was associated with overall reductions in patient mortality in teaching-intensive hospitals (Volpp et al. 2007, Shetty & Bhattacharya 2007). However, there were heterogenous impacts on patient mortality rates with mortality rates remaining unchanged for surgical patients (Shetty & Bhattacharya 2007). Duty hour restrictions have also been associated with longer term reductions in inpatient mortality for high-risk patients with pneumonia, congestive heart failure, and strokes in teaching hospitals (Jena, Prasad, & Romley 2014).

Turning towards the reform's impact on physicians, prior to the reform there were concerns about how reduced work during residency would impact physician training and long-term quality. For example, some physicians feared that residents would be less well-trained and unprepared for independent practice after the completion of their residency. Subsequent studies suggest, however, that the reform reduced reported levels of resident burnout, especially among first year residents, but appeared to have had no major impact on the quality of residents' training and education (Martini et al. 2014, Hutter et al. 2006, Jena et al. 2014). However, the work that residents would have done prior to the work hour constraints seems to have shifted to supervising physicians (known as attending physicians), as post reform attending surgeons reported that their quality of life in and out of the hospital was slightly worse (Hutter et al. 2006). The 2003 reform also had the unintended impact of encouraging more women to enter certain specialties that previously involved greater hours of training. Wasserman (2023) details how the

reform shifted women's labor supply from less time-intensive specialties to more time intensive specialties as those specialties reduced their weekly hours to comply with the 2003 reform.

2.3 2011 Duty Hour Reform

To further increase patient and resident safety, in 2011 the ACGME implemented an additional work reform which prohibited first year residents from working more than 16 consecutive hours (Riebschleger & Nasca 2011). Prior to this change, first year residents worked the longest hours of any resident cohort, sometime nearing 30 hours in a single stretch, and were found to make more errors when working those longer hours (Riebschleger & Nasca 2011). Overall, the restrictions on first year hours were designed to create a more structured learning environment that would enable first year residents to develop the skills to properly care for patients.

The 2011 duty hour reform appears to have had little impact on either patient outcomes or physician well-being. While the reform was effective in reducing first year resident hours, there were no significant changes in first year residents' hours slept, well-being scores, or presence of depressive symptoms (Sen et al. 2013). Furthermore, post reform, junior surgical residents had less experience and clinical responsibilities were shifted to more senior residents (Awan et al. 2021). However, Rajaram et al. (2014) report that there was no change in resident performance on board examinations post reform, indicating that even if first year residents did receive less experience, their knowledge base, as measured by a standardized written exam, was not harmed in the long run.

Several studies have also found that patient outcomes were unchanged after the reform, with no measurable impact found on general surgery patient outcomes (Rajaram et al. 2014), 30-

day morality rates or 30-day all cause readmission rates for Medicare beneficiaries (Patel et al. 2014), or serious patient complications (Awan et al. 2021).

While these results suggest that the 2011 duty hour reform has had little impact on physician behavior or patient outcomes, little is known about how these work reforms have affected the physical health of physicians. Our study seeks to examine one dimension of this issue by examining if the 2011 duty hour reform improved physicians' birth outcomes.

3 Data

To measure the potential impact of being a physician on a mother's birth outcomes we use Texas birth records from 2007 to 2014. Texas birth records include demographic information about the mother and father (including their names), information about the labor and delivery process, and a variety of birth outcomes. The subset of birth records we obtained from the Texas Department of State Health Services included births where at least one parent had a doctorate (PhD, EdD) or a terminal, doctoral level professional degree (MD, DDS, DVM, LLB, or JD).

For the purposes of our study, we constructed a sample of mothers between 26 and 45 years old which spans from the age most people begin their residency to the age commonly regarded by obstetricians as the end of a woman's fertility period. We further narrowed our sample by only including mothers that listed their occupation as an equivalent of "physician" or "lawyer".[1]

[1] Since the occupations were self-reported in the birth records, there were many misspellings in mother's occupation field. Spellings that either missed a few letters or included a phonetically similar letter (ex. s instead of c) were assumed to be misspellings and were assigned the correct occupation. For example, "physisian" was considered to be "physician" and "anestheoligst" was considered "anesthesiologist". If a misspelled occupation was potentially close to an equivalent of physician or lawyer, the spelling was entered into Google to see if it was a common misspelling of the occupation (ex. "optimologist" was considered to be "ophthalmologist"). All misspellings were evaluated by hand by the researchers.

After narrowing the sample to mothers who identified either as a physician or lawyer, we attempted to identify the specialties of physician mothers. To find specialties of physician mothers, we first identified if the mother included a specialty in her self-reported occupation (e.g. a mother could self-report her occupation as "surgeon"). If the self-reported occupation was simply an equivalent of "physician," we then matched the mother's first and last name and state (Texas) to the CMS National Plan and Provider Enumeration System National Provider Identifier (NPI) registry, which lists the taxonomy numbers associated with the physician's specialty. We did not include matches where multiple NPIs matched to one mother unless one of the matches was a physician practicing in Texas. If there were multiple matched physicians practicing in Texas, the match was not included. Through either self-reported specialties on the birth records or through matching the NPI registry, we identified specialties for approximately 70% of the physician mothers.

We then used the specialties to create a sub sample of surgeons and non-surgeons. The surgeon sample included physicians in the specialties of general surgery, obstetrics and gynecology (OBGYN), orthopedics, otolaryngology, plastic surgery, and urology. The non-surgeon sample were those physicians whose identified specialties were in the complement of this group.

4 Methodology.

We compare the birth outcomes of physician mothers to those of lawyer mothers since lawyers are a comparable group to physicians in terms of educational background. Despite similar education requirements, however, physicians and lawyers are subject to very different work environments. Physicians' work is more physically demanding due to its long hours, prolonged periods of standing, and moments of great stress. This difference is magnified for

surgeons, the subgroup of physicians that work the longest hours and are on their feet for the majority of those hours. By comparing mothers in these educationally similar occupations, we attempt to estimate the impact of the strenuous work environment on physician mothers' and surgeon mothers' birth outcomes. Importantly, however, since individuals are not randomized or quasi-randomized to occupation, our results should be interpreted descriptively.

We compare five different birth outcomes between physicians and lawyers and among physicians, between surgeons and non-surgeons: newborn's birth weight (in grams), length of the pregnancy (in weeks), and binary indicators for pre-term delivery (a delivery that occurred before 37 weeks of pregnancy), cesarean delivery, and the presence of an abnormal birth condition. Included in newborn abnormal birth conditions are indicators for admission to the neo-natal intensive care unit (NICU), receiving surfactant replacement therapy to manage respiratory distress syndrome, requiring antibiotics for suspected neonatal sepsis, having seizure or serious neurologic dysfunction, and significant brain injury.[2]

Summary statistics of our sample are included in **Table 1**. Demographically, physicians and lawyers are quite similar. For example, the age of mothers in both groups is, on average, approximately 33 years old. Physicians are slightly more likely to have had a prior poor pregnancy outcome while lawyers are more likely to smoke during pregnancy. Lawyers are also more likely to be non-Hispanic white than physicians, and physicians are slightly more likely to be non-Hispanic Asian than lawyers.

[2] The original Texas birth data includes two measures of newborn ventilator usage in the newborn abnormal conditions ("assisted ventilation required immediately following delivery" and "assisted ventilation required for more than 6 hours"). However, in 2011, neonatologists began using non-invasive positive pressure ventilators (NIPPV) for newborns (De Jesus Rojas et al. 2017). The introduction of this new technology, which could be a substitute for traditional ventilation in some situations (Garg & Sinha 2013), coincides directly with the 2011 ACGME duty hour reform that we are studying. Further, we are concerned that physicians would adopt this new less invasive procedure at different rates than non-physicians. Given these concerns, we do not study newborn ventilation rates.

4.1 Descriptive Models

We begin by estimating two descriptive models to identify if being a physician is associated with worse birth outcomes compared with being a lawyer.

We estimate the following descriptive model on our full sample of physician and lawyer mothers:

$$Y_{ict} = \beta physician_i + \delta \boldsymbol{X}_i + \alpha_t + \alpha_c + \epsilon_{ict} \quad (1)$$

where Y_{ict} is one of the birth outcomes outlined above measured for mother i in county c in year t. $physician_i$ is an occupation binary variable that indicates if the mother is a physician. $\boldsymbol{X}_i$ is the set of demographic and behavior controls, including mother's age and race, number of prenatal visits during this pregnancy, number of cigarettes smoked during pregnancy, a binary indicator for having diabetes prior to pregnancy or developing gestational diabetes, and a binary indicator for if the mother experienced a prior poor pregnancy outcome (defined as perinatal death, a newborn small for gestational age, and intrauterine growth restriction). Finally, α_t and α_c are year and county fixed effects respectively. The coefficient of interest is β which identifies the difference in birth outcomes between physicians and lawyers.

We then estimated an analogous model restricted to physicians and compared birth outcomes between surgeons and non-surgeons, adjusting for the same factors described above. This specification included the variable $surgeon_i$, which indicates if the physician is in a surgical specialty. All other variables in the model are unchanged and as previously described. Here the coefficient of interest β identifies if surgeon physicians have better or worse birth outcomes than non-surgeon physicians.

Table 1: Summary Statistics

	Full Sample		Physicians		Lawyers	
VARIABLES	N	Mean	N	Mean	N	Mean
Dependent Variables						
Birth weight (grams)	19,210	3,231	9,841	3,171	9,369	3,295
Length of pregnancy	18,710	38.34	9,605	38.25	9,105	38.43
Pre-term delivery	18,710	0.128	9,605	0.134	9,105	0.121
C-section	19,210	0.434	9,841	0.415	9,369	0.453
Newborn abnormal conditions	19,210	0.091	9,841	0.093	9,369	0.089
Occupation Variables						
Physician	9,841					
Lawyer	9,369					
Surgeon	7,061	0.183				
Demographic and Health Controls						
Mother's age	19,210	33.50	9,841	33.63	9,369	33.35
Prenatal visits (n)	19,210	11.16	9,841	10.83	9,369	11.51
Cigarettes smoked during pregnancy (n)	19,210	0.026	9,841	0.010	9,369	0.044
Diabetic	19,210	0.046	9,841	0.048	9,369	0.044
White	19,210	0.611	9,841	0.492	9,369	0.735
Black	19,210	0.077	9,841	0.082	9,369	0.071
Asian	19,210	0.167	9,841	0.270	9,369	0.059
Hispanic	19,210	0.130	9,841	0.138	9,369	0.122
Prior poor pregnancy outcome	19,210	0.007	9,841	0.010	9,369	0.005

Pre-term birth consists of pregnancies that were less than 37 weeks at time of birth. Newborn abnormal conditions include NICU admission, surfactant replacement therapy, required antibiotics for suspected neonatal sepsis, seizure or serious neurologic dysfunction, and significant brain injury. Surgeon category includes physicians in the specialties: General Surgery, OBGYN, Orthopedics, Otolaryngology, Plastic Surgery, and Urology.

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4.2 Difference-in-Differences Models

Following a descriptive analysis of birth outcomes between physicians and lawyers and between surgeons and non-surgeon physicians, we then turn toward evaluating if the 2011 ACGME duty hour reform impacted birth outcomes of physicians. Here we compare physician and lawyer mothers who gave birth prior to the 2011 ACGME duty hour reform to physician and lawyer mothers who gave birth after the reform. While the 2011 duty hour reform pertained just to first-year residents there is evidence that the effects of the reform spilled over to older residents and attending physicians (Awan et al. 2021). As such, we estimate the effect for all physicians instead of just first year residents. To do so we estimate the following difference-in-differences model:

$$Y_{ict} = \beta_1 physician_i + \beta_2 postrule_i + \beta_3 (physician_i * postrule_i) + \boldsymbol{X}_i + \alpha_t + \alpha_c + \epsilon_{ict} \quad (2)$$

where $postrule_i$ indicates if the birth took place 9 months after the rule change went into effect, thereby focusing on mothers who may have been exposed to reduced work hours during the entirety of their pregnancy. Since the duty hour reform went into effect on July 1, 2011, $postrule_i$ equals one for births that occurred on or after April 1, 2012. All other variables have the same meaning as in the descriptive models. Here β_3 is our coefficient of interest and identifies if the 2011 duty reform had any impact on the birth outcomes of physicians.

We estimate a second set of DID models to assess whether the 2011 ACGME duty hour reform had heterogenous effects on surgeons and non-surgeons. Specifically, we stratify the DID model based on whether or not the physician is a surgeon, replacing the physician occupation variable from equation (2) with an indicator variable for being a surgeon. In one model, we are comparing the birth outcomes of lawyers to those of surgeons, and in the second model, we are

comparing the birth outcomes of lawyers to those of non-surgeons. Depending on the which subgroup is included in the stratification, β_3 identifies if the 2011 duty hour reform improved the birth outcomes of surgeons (non-surgeons) as compared to lawyers.

5 Results

5.1 Descriptive Results

Table 2 reports our main descriptive results where we compare 26-45 year-old physician mothers to lawyer mothers as outlined in equation (1). Our preferred models (the even numbered models) include control variables. We find that physicians have 2.3% lower birth weights and 0.32% shorter pregnancy lengths than lawyers. Consistent with slightly shorter pregnancies, we also find that physicians have a slight increase in the likelihood of pre-term delivery, but the estimate is only significant at the 10% level. Similar to Johnson & Rehavi (2016) and Frakes et al. (2021) we observe that physicians are 9.9% less likely to have c-sections than lawyers. We find no significant results when comparing the incidence of newborn abnormal conditions of physician mothers to lawyer mothers.

We then attempt to identify which group of physicians, if any, is driving these differences between physicians and lawyers. We first stratify our results by race.[3] The majority of our sample (around 61%) are non-Hispanic white mothers, with 7.7%, 16.7% and 13% of the sample being non-Hispanic Black, non-Hispanic Asian, and Hispanic mothers, respectively.[4] The results for our birth outcome variables are shown in **Figure 1** and **Appendix Table 1A**. Non-Hispanic white, non-Hispanic Asian and Hispanic mothers are driving the decrease in birth weights observed among physicians, with non-Hispanic Asian mothers experiencing the largest reduction

[3] We also stratified the results by ages of the mothers, 26-35 and 36-45, but there were no significant differences in birth outcomes between the age groups.
[4] The rest of the sample, 1.5%, identify as multi-racial.

in birth weight. The decrease in pregnancy length is driven by non-Hispanic white and non-Hispanic Asian mothers, and the decline in cesarean delivery appears to be due primarily to the decrease experienced by non-Hispanic white mothers. As in the main descriptive model, there is no statistically significant difference in the likelihood of pre-term delivery or incidence of newborn abnormal conditions between physicians and lawyers.

We then examine whether heterogeneous effects may exist for different types of physicians: surgeons versus non-surgeons. We estimate the previously described analogous model on the sub-sample of physicians that have identified specialties. In this model, we compare 26-45 year-old surgeons to non-surgeons. Our results are outlined in **Table 3**. Overall, surgeons experience worse birth outcomes than non-surgeons. Surgeons have birth weights that are 2.3% lower than non-surgeons and pregnancies that are 0.9% shorter than non-surgeons. We also find that surgeons are 32.3% more likely to deliver pre-term. We do not find any significant differences in rates of caesarean deliveries between surgeons and non-surgeons or differences in the incidence of newborn abnormal conditions.

Table 2: Birth Outcomes among Physicians vs. Lawyers

	Birth Weight (grams)		Pregnancy Length (weeks)		Pre-term Delivery		C-Section		Newborn Abnormal Conditions	
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Physician	-120.701***	-75.844***	-0.175***	-0.122***	0.012**	0.010*	-0.035***	-0.043***	0.003	-0.001
	(8.724)	(9.108)	(0.034)	(0.036)	(0.005)	(0.005)	(0.007)	(0.008)	(0.004)	(0.004)
Additional Controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Observations	19,210	19,210	18,710	18,710	18,710	18,710	19,210	19,210	19,210	19,210
R-squared	0.020	0.038	0.009	0.032	0.006	0.017	0.013	0.040	0.008	0.017
Dependent variable mean	3231		38.34		0.128		0.434		0.0908	

Each model includes year and county of birth fixed effects. Additional controls include mother's age, number of prenatal visits, diabetes indicator, race indicators for white, Black, Asian, and Hispanic, indicator for a prior poor pregnancy outcome, and number of cigarettes smoked during pregnancy. Pre-term birth consists of pregnancies that were less than 37 weeks at time of birth. Newborn abnormal conditions include NICU admission, surfactant replacement therapy, required antibiotics for suspected neonatal sepsis, seizure or serious neurologic dysfunction, and significant brain injury. Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Figure 1: Birth Outcomes among Physicians vs. Lawyers by Race

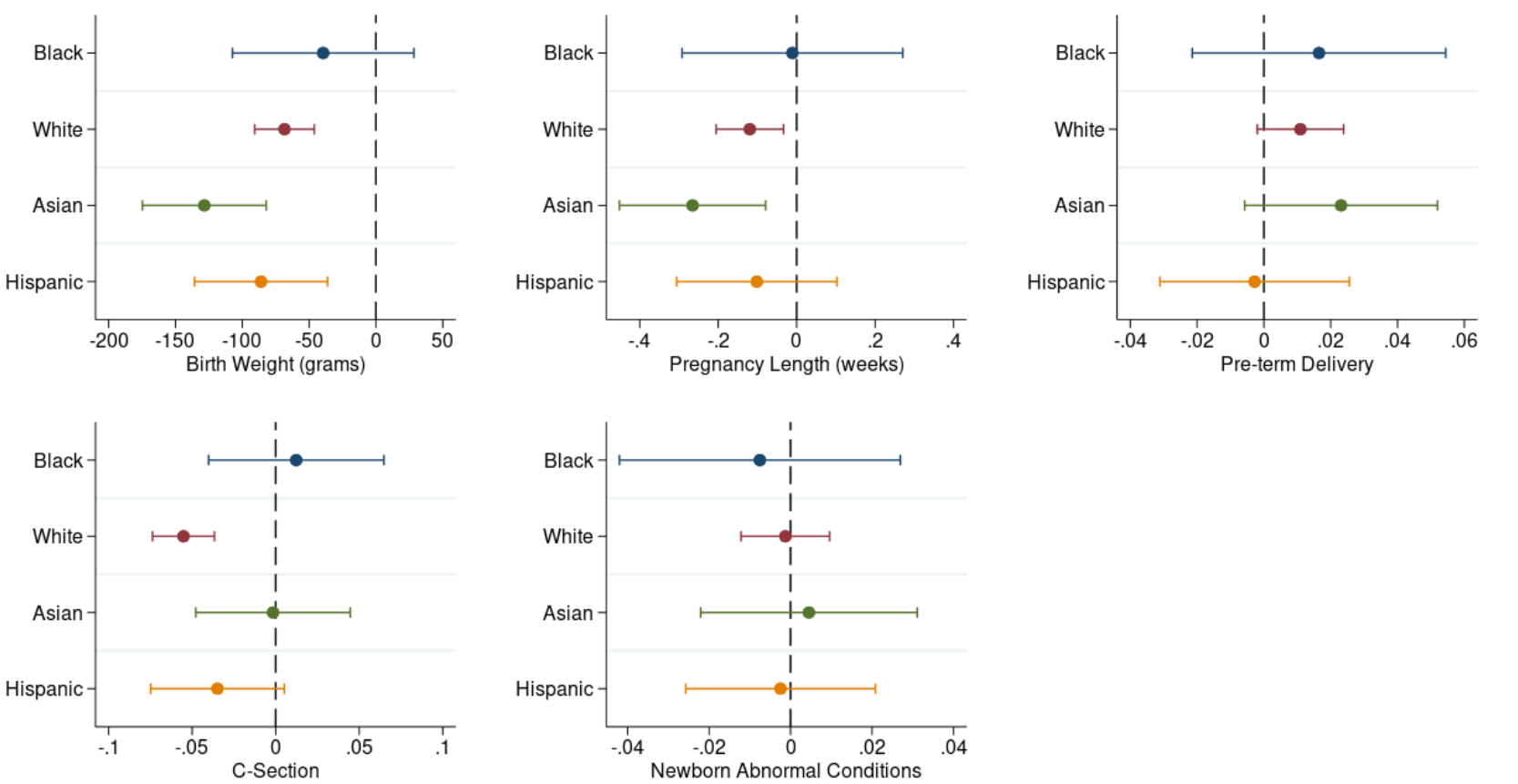

Table 3: Birth Outcomes among Surgeons vs. Non-Surgeons

	Birth Weight (grams)		Pregnancy Length (weeks)		Pre-term Delivery		C-Section		Newborn Abnormal Conditions	
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Surgeon	-36.089*	-71.557***	-0.342***	-0.338***	0.045***	0.045***	0.019	0.027*	0.011	0.013
	(18.869)	(18.943)	(0.076)	(0.076)	(0.012)	(0.012)	(0.015)	(0.015)	(0.009)	(0.010)
Additional Controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Observations	7,061	7,061	6,887	6,887	6,887	6,887	7,061	7,061	7,061	7,061
R-squared	0.019	0.050	0.018	0.041	0.015	0.026	0.018	0.045	0.011	0.018
Dependent variable mean	3174		38.22		0.139		0.416		0.0950	

Each model includes year and county of birth fixed effects. Additional controls include mother's age, number of prenatal visits, diabetes indicator, race indicators for white, Black, Asian, and Hispanic, indicator for a prior poor pregnancy outcome, and number of cigarettes smoked during pregnancy. Surgeon category includes physicians in the specialties: General Surgery, OBGYN, Orthopedics, Otolaryngology, Plastic Surgery, and Urology. Pre-term birth consists of pregnancies that were less than 37 weeks at time of birth. Newborn abnormal conditions include NICU admission, surfactant replacement therapy, required antibiotics for suspected neonatal sepsis, seizure or serious neurologic dysfunction, and significant brain injury. Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

5.2 Impact of the 2011 ACGME work hour reductions

Given that physicians tend to experience worse birth outcomes than lawyers, we estimate whether the 2011 ACGME duty hour reform, which improved working conditions for physicians in training, improved physicians' birth outcomes relative to lawyers. **Table 4** reports the results from equation (2). Our key variable of interest, the difference-in-differences estimate of changes in birth outcomes among physicians compared with lawyers before versus after duty hour reform (variable, *Physician post rule)*, does not have a significant impact on birth weight, pregnancy length, or pre-term delivery, the three outcomes that were worse for physicians in our descriptive model. The effect on the rate of caesarean delivery is positive, but only significant at the 10% level. Finally, there was no significant impact on the incidence of newborn abnormal conditions.

Since the 2011 duty hour rule may have affected working conditions of different specialties differently, we also stratified our model comparing surgeons to lawyers and non-surgeon physicians to lawyers. **Table 5** shows the results for that model. Similar to the general difference-in-differences model, our variable of interest is not associated with significant changes in birth weight, pregnancy length, pre-term delivery, or incidence of newborn abnormal conditions. In this model, only non-surgeons have a positive increase in the rate of caesarean deliveries, but it is only significant at the 10% level.

Table 4: Impact of Duty Hour Reform on Birth Outcomes of Physicians

	Birth Weight (grams)		Pregnancy Length (weeks)		Pre-term Delivery		C-Section		Newborn Abnormal Conditions	
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Physician post reform	10.097	9.796	-0.034	-0.028	0.006	0.005	0.029*	0.028*	0.009	0.008
	(17.612)	(17.454)	(0.070)	(0.069)	(0.010)	(0.010)	(0.015)	(0.015)	(0.009)	(0.009)
Physician	-124.737***	-79.757***	-0.163***	-0.113**	0.010	0.008	-0.046***	-0.054***	-0.001	-0.004
	(10.860)	(11.208)	(0.042)	(0.044)	(0.006)	(0.007)	(0.009)	(0.009)	(0.005)	(0.006)
Post reform	1.160	5.758	0.141***	0.148***	-0.007	-0.007	-0.026**	-0.030***	-0.005	-0.005
	(12.796)	(12.733)	(0.050)	(0.049)	(0.007)	(0.007)	(0.011)	(0.011)	(0.006)	(0.006)
Additional Controls	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Observations	19,210	19,210	18,710	18,710	18,710	18,710	19,210	19,210	19,210	19,210
R-squared	0.020	0.038	0.008	0.031	0.005	0.017	0.013	0.039	0.008	0.017
Dependent variable mean	3231		38.34		0.128		0.434		0.0908	

Each model includes county of birth fixed effects. Additional controls include mother's age, number of prenatal visits, diabetes indicator, race indicators for white, Black, Asian, and Hispanic, indicator for a prior poor pregnancy outcome, and number of cigarettes smoked during pregnancy. The DID model compares physician and lawyer mothers who gave birth prior to the 2011 duty hour change to physician and lawyer mothers who gave birth after the rule change. 'Physician post reform' estimates the impact of the effect of the 2011 duty hour rule change on physician mothers' birth outcomes. Pre-term birth consists of pregnancies that were less than 37 weeks at time of birth. Newborn abnormal conditions include NICU admission, surfactant replacement therapy, required antibiotics for suspected neonatal sepsis, seizure or serious neurologic dysfunction, and significant brain injury. Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 5: Impact of Duty Hour Reform on Birth Outcomes - Surgeons vs. Non-Surgeons

	Birth Weight (grams)		Pregnancy Length (weeks)		Pre-term Delivery		C-Section		Newborn Abnormal Conditions	
	Surgeon	Non-Surgeon	Surgeon	Non-Surgeon	Surgeon	Non-Surgeon	Surgeon	Non-Surgeon	Surgeon	Non-Surgeon
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Physician post reform	0.347	17.542	-0.040	-0.059	0.003	0.011	0.022	0.033*	0.015	0.008
	(35.921)	(20.106)	(0.146)	(0.080)	(0.023)	(0.012)	(0.029)	(0.017)	(0.018)	(0.010)
Physician	-134.945***	-68.858***	-0.410***	-0.066	0.048***	0.001	-0.038*	-0.060***	0.008	-0.004
	(23.591)	(13.046)	(0.091)	(0.052)	(0.015)	(0.007)	(0.020)	(0.011)	(0.012)	(0.006)
Post reform	4.603	5.716	0.147***	0.149***	-0.007	-0.007	-0.030***	-0.029***	-0.005	-0.006
	(12.751)	(12.744)	(0.049)	(0.049)	(0.007)	(0.007)	(0.011)	(0.011)	(0.006)	(0.006)
Observations	10,662	15,137	10,361	14,736	10,361	14,736	10,662	15,137	10,662	15,137
R-squared	0.035	0.037	0.043	0.033	0.023	0.017	0.040	0.038	0.022	0.019
Additional Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dependent variable mean	3276	3252	38.37	38.38	0.128	0.125	0.451	0.438	0.0902	0.0903

Each model includes county of birth fixed effects. Additional controls include mother's age, number of prenatal visits, diabetes indicator, race indicators for white, Black, Asian, and Hispanic, indicator for a prior poor pregnancy outcome, and number of cigarettes smoked during pregnancy. The DID model compares surgeon (non-surgeon) and lawyer mothers who gave birth prior to the 2011 duty hour change to surgeon (non-surgeon) and lawyer mothers who gave birth after the rule change. 'Physician post reform' estimates the impact of the effect of the 2011 duty hour rule change on surgeon (non-surgeon) mothers' birth outcomes. Surgeon category includes physicians in the specialties: General Surgery, OBGYN, Orthopedics, Otolaryngology, Plastic Surgery, and Urology. Pre-term birth consists of pregnancies that were less than 37 weeks at time of birth. Newborn abnormal conditions include NICU admission, surfactant replacement therapy, required antibiotics for suspected neonatal sepsis, seizure or serious neurologic dysfunction, and significant brain injury. Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

6 Discussion

Our descriptive results, while not causal, suggest that physicians tend to have worse birth outcomes than lawyers, even after adjustment for several maternal characteristics that are correlated with birth outcomes (see **Figure 2A** for a visual representation of the difference in birth weights). Several studies of the relationship between pollution and birth outcomes help put the magnitude of physician-lawyer birth outcome differences identified in this study into context. For example, in an analysis of the impact of the hidden diesel fuel pollution from Volkswagen's 2008 "clean diesel" cars on birth outcomes, Alexander and Schwandt (2022) found a 0.19% decrease in birth weight and a 0.04% decrease in gestational age for each additional "clean diesel" car per 1,000 cars. Because the public was unaware that the "clean diesel" cars actually emitted much more pollution than comparable gas-fueled cars, the rollout of the "cheating" cars, as they became known, serves as a natural experiment to study the impact of pollution on birth outcomes. Due to the nature of who purchased the "cheating" diesel cars, higher educated and primarily white people, the sample of the study is very similar to the sample in our model. As such, while not necessarily causal, our findings of physicians having 2.3% lower birth weights and 0.32% shorter pregnancies compared with lawyers are similar in magnitude with the effects observed for diesel fuel pollution. In another study of air pollution's impact on birth outcomes, Currie and Walker (2011) find that incidence of premature birth is reduced by 10.8% for mothers within 2 kilometers of a toll plaza when E-ZPass is introduced, due to a reduction in local pollution from cars moving more quickly through tolls. While only significant at the 10% level, we estimate that physicians are 7.8% more likely to deliver pre-term, consistent in magnitude with the impacts observed by Currie and Walker (2011). If causal, our findings suggest that the

strenuous work environment of physicians, particularly surgeons, may be associated with modest but meaningful reductions in infant gestational age and birth weight.

Comparing our results to national descriptive birth outcomes, we find that the difference in birth weights between physicians and lawyers is about 30% of the 2007-2014 non-Hispanic Black to non-Hispanic white gap in average birth weights which was 250.53 grams.[5] Further, the difference in birth weights between physicians and lawyers is larger than the gap in average birth weight between mothers with a high school diploma and those with a doctoral or professional degree (60.60 grams) and the gap between rural-based and metro-based mothers (3.67 grams). In terms of pregnancy length, the difference between physicians and lawyers is similar to or larger than the gap between rural-based and metro-based mothers (0.04 weeks) and the gap between mothers with a high school diploma and mothers with a doctoral or professional degree (0.16 weeks), and the difference is about 27% of the difference in average pregnancy length between non-Hispanic white and non-Hispanic Black mothers (0.46 weeks). Overall, the physician-lawyers difference in birth weight and pregnancy length that we find is comparable to or larger than the birth outcome gaps due to residential location or education and have magnitudes that are approximately 30% of the sizeable gap in birth outcomes between non-Hispanic Black and non-Hispanic white mothers.

Our results contrast those from Dave and Yang (2022) and Baum (2005), which found that working in a strenuous job had no effect on birth weight, pregnancy length, and pre-term delivery. However, Katz et al. (1988) identified that physicians are more likely to experience pre-term labor. Further, the characteristics of physicians' work (long hours, night and shift work, and

[5] Reported gaps in average birth weights and pregnancy lengths are national averages from 2007 to 2014 and were obtained from the CDC National Vital Statistics System's WONDER database. The reported national averages are from the Natality Records 2007-2022.

long periods of standing) have been medically associated with adverse birth outcomes such as pre-term birth and lower birth weights (Mozurkewich et al. 2000, Bonzini, Coggon, and Palmer 2007, Palmer et al. 2013). Therefore, our descriptive results have precedence in the literature though we remain unable to speak to the causal nature of being a physician on birth outcomes.

Further, in our descriptive model physicians were less likely to give birth via a caesarean delivery. This result, which has been found by others (Johnson & Rehavi 2016, Frakes et al. 2021), is likely related to the increasingly common medical advice that, if possible, mothers should avoid giving birth via caesarean delivery. Physicians are more likely to understand the current and future risks associated with a caesarean delivery than lawyers and thus more likely to avoid this form of delivery if possible. Similar to the findings in Johnson and Rehavi (2016) and Chen et al. (forthcoming) physicians use their medical expertise to improve their own care.

Our study suggests that the difference in birth outcomes between physicians and lawyers may largely be driven by surgeons. While all medical specialties require some level of physical exertion, particularly during the years of residency training where hours are long and overnight and lengthy shift work are common, surgeons tend to have more physically demanding tasks. Surgeons work longer weekly hours, are often required to stand for long periods of time, and often experience periods of intense stress. Moreover, some studies suggest that the workplace environment towards women is particularly difficult for female surgeons (Lombarts & Verghese 2022, Hutchison 2020) with Sudol et al. (2021) reporting that 94% of surveyed female surgeons report experiencing sexist microaggressions including overhearing or seeing degrading female terms and images. The female surgeons who reported experiencing sexist microaggressions were then more likely to experience burnout (Sudol et al. 2021). Medical studies suggest that these physical aspects of the job are associated with adverse birth outcomes (Palmer et al. 2013,

Bussières et al. 2015). Surgeons experiencing worse birth outcomes than non-surgeons provides evidence for our theory that the physically strenuous job of being a physician may lead to adverse birth outcomes compared with being a lawyer.

Given that the 2011 ACGME duty hour reform was partly intended to improve working conditions of physicians in training, we would expect the reform to improve physician's birth outcomes, however, our difference-in-differences results suggest that the work reform had little effect. Our results confirm what others (Sen et al. 2013) have found; while the duty hour reform was binding, there was little actual impact on physician well-being, as measured by hours slept, depressive symptoms, and well-being scores. There is suggestive evidence that non-surgeons may have benefited more from the work reform than surgeons, which aligns with previous work that outlined the limited impact that previous ACGME work reforms had for surgical outcomes (Shetty & Bhattacharya 2007), however, we observed no difference in the effect of the 2011 work hour reform on birth outcomes of surgeons vs. non-surgeon physicians.

While our study cannot be definite about the impact of improved working conditions on physician's birth outcomes brought about by the 2011 work hour reform, we can speak generally about whether the work reform could have improved birth outcomes enough to bring them on par with birth outcomes from lawyers. Given the 95% confidence interval for the difference-in-differences coefficient impact of work hour reform on birth weight [-23.46 to 44.96 grams] we can rule out that the duty hour reform increased birth weights by enough to make up for the already existing difference between physicians and lawyers (-75.84 grams). A similar argument can be made for the pregnancy length [95% CI: -0.16 to 0.11 weeks] since the magnitude of the difference in pregnancy length between physicians and lawyers was -0.12 weeks. See **Figure 3A** for a visual representation. To improve birth outcomes of physicians enough to eliminate the

difference between physicians and lawyers, additional work reforms or changes in the work environment would be needed.

7 Conclusion

Given growing evidence that a mother's environment and experiences during pregnancy may impact the health of her infant, we examined the potential impact on infant health of working in a particularly physically demanding and stressful high-attainment occupation, medicine. We compared birth outcomes of physician mothers to those of a comparable, highly educated group, lawyer mothers. Though our findings are not causal, we found that infants born to physicians have 2.3% (75.84 grams) lower birth weights and 0.32% (0.12 weeks) shorter pregnancies than infants born to lawyers. The decline in birth outcomes appears to be driven primarily by surgeons, who among physicians often perform the most physically demanding work.

We also explored the impact of the 2011 ACGME duty hour reform, which improved the work environment of physicians in training on physician's birth outcomes. Our finding suggests that the duty hour reform had no impact on birth outcomes of physicians compared with lawyers. Further, given the upper bounds of the estimate's confidence interval, the duty hour rule change would not have been expected to close the gap in birth outcomes between physicians and lawyers.

While our findings are primarily descriptive, they raise the possibility that the long and stressful hours that physicians undertake early in their careers may be associated with slightly worse birth outcomes, particularly among surgeons. Future research could assess this issue by leveraging natural experiments in which otherwise similar individuals are plausibly randomly exposed to careers in medicine, as Ketel et al. (2016) and Chen et al. (2022) have evaluated in

the context of medical school lotteries in the Netherlands and Sweden, respectively. Additionally, as we find, that work hour reforms did little to improve birth outcomes of physicians compared with lawyers, to mitigate any adverse effects associated with careers in medicine, stronger work reforms or further changes in the work environment may be needed.

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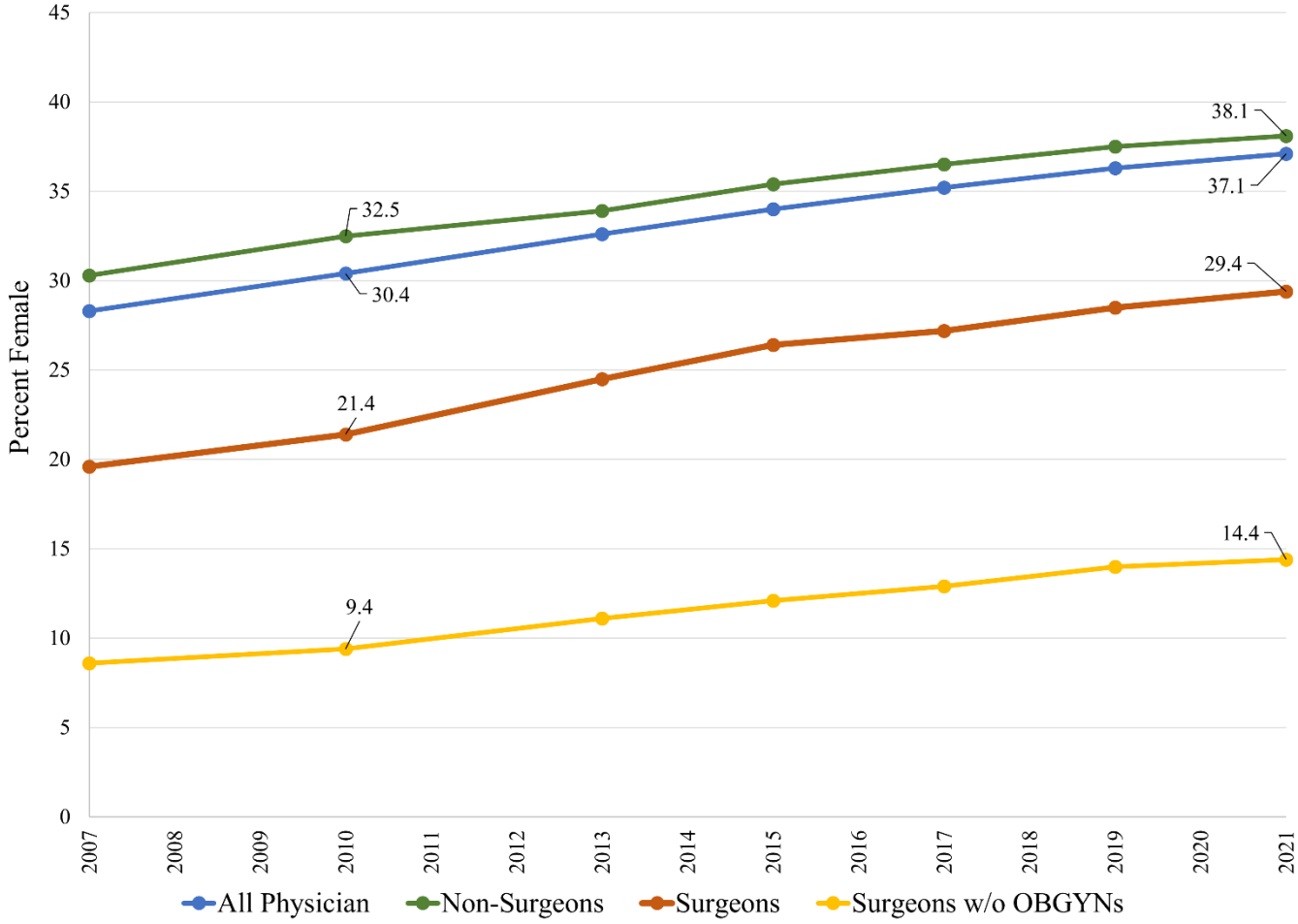
Figure and Table Appendix

Figure 1A: Share of Active Physicians that Identify as Female



Source: AAMC Physician Specialty Data Report 2008-2022

Figure 2A: Difference in Birth Weight (in grams) Between Physicians vs. Lawyers

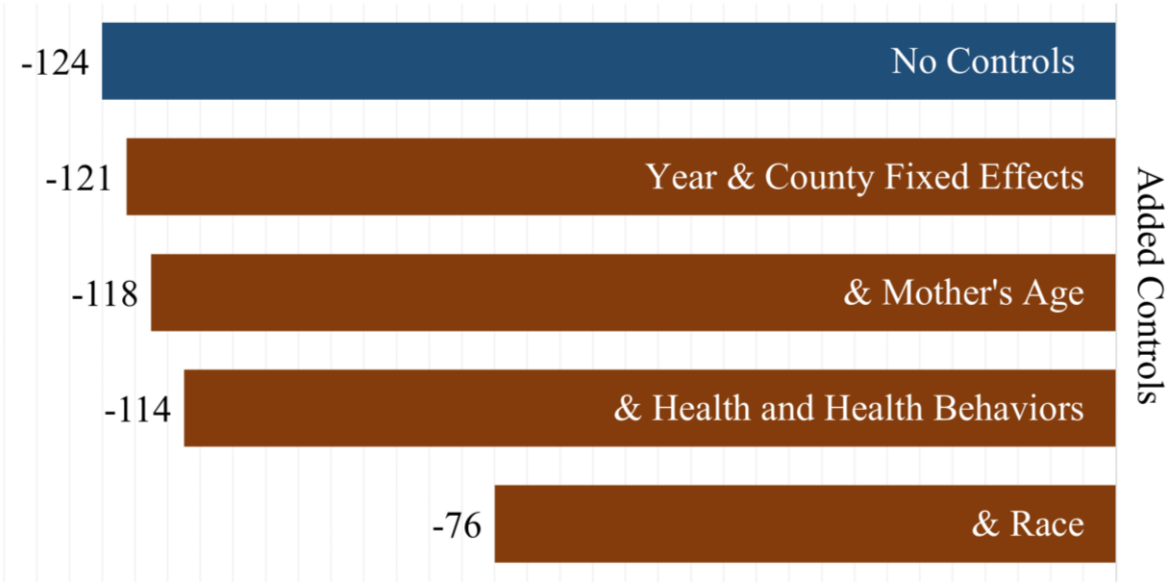


Figure 3A: DID 95% Confidence Intervals

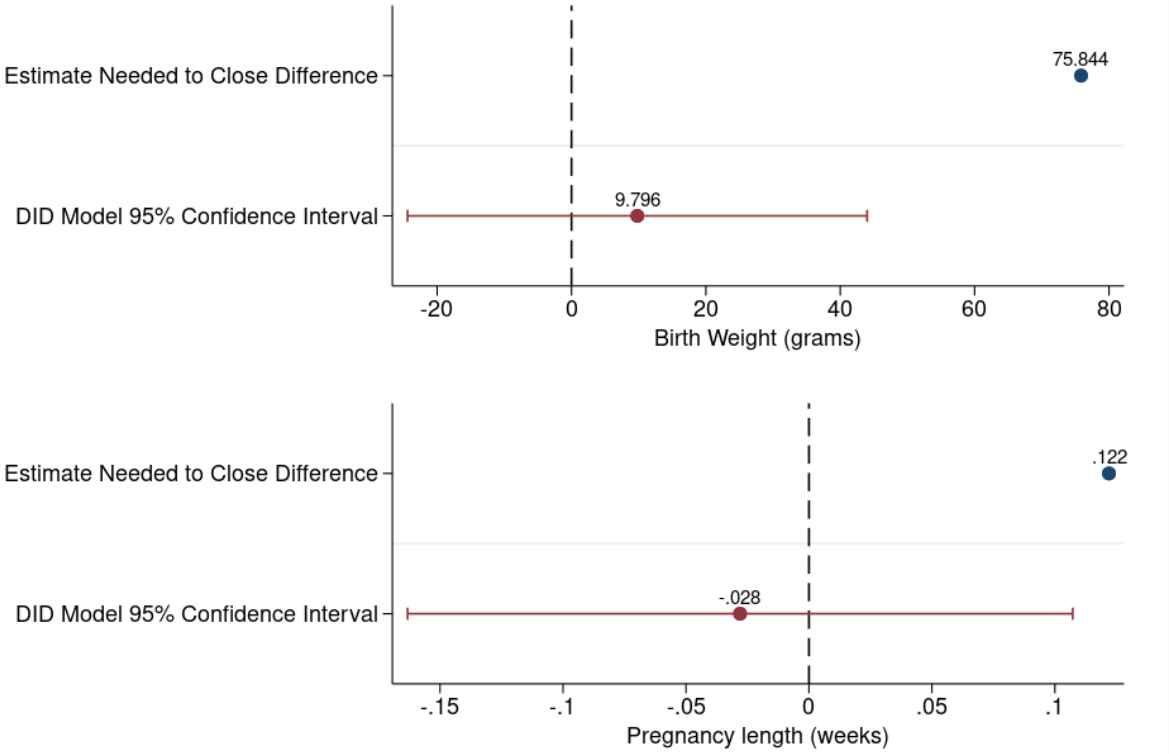


Table 1A: Birth Outcomes among Physicians vs. Lawyers by Race

	Birth Weight (grams)				Pregnancy Length (weeks)				Pre-term Delivery			
	Black	White	Asian	Hispanic	Black	White	Asian	Hispanic	Black	White	Asian	Hispanic
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Physician	-39.472	-68.417***	-128.438***	-85.989***	-0.011	-0.119***	-0.265***	-0.102	0.016	0.011*	0.023	-0.003
	(34.616)	(11.386)	(23.632)	(25.389)	(0.143)	(0.044)	(0.095)	(0.104)	(0.019)	(0.007)	(0.015)	(0.014)
Observations	1,476	11,734	3,208	2,501	1,427	11,432	3,124	2,443	1,427	11,432	3,124	2,443
R-squared	0.030	0.022	0.025	0.041	0.050	0.035	0.028	0.055	0.074	0.019	0.028	0.033
Additional Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dependent variable mean	3126	3292	3071	3216	38.08	38.41	38.30	38.22	0.148	0.126	0.122	0.133

Table 1A cont.: Birth Outcomes among Physicians vs. Lawyers by Race

	C-Section				Newborn Abnormal Conditions			
	Black	White	Asian	Hispanic	Black	White	Asian	Hispanic
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Physician	0.012	-0.055***	-0.002	-0.035*	-0.008	-0.001	0.005	-0.002
	(0.027)	(0.009)	(0.024)	(0.020)	(0.018)	(0.006)	(0.014)	(0.012)
Observations	1,476	11,734	3,208	2,501	1,476	11,734	3,208	2,501
R-squared	0.068	0.041	0.035	0.087	0.043	0.019	0.023	0.033
Additional Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dependent variable mean	0.453	0.423	0.424	0.489	0.118	0.0874	0.0945	0.0848

Each model includes year and county of birth fixed effects. White, Black, and Asian mothers are non-Hispanic white, non-Hispanic Black, and non-Hispanic Asian respectively. Pre-term birth consists of pregnancies that were less than 37 weeks at time of birth. Newborn abnormal conditions include NICU admission, surfactant replacement therapy, required antibiotics for suspected neonatal sepsis, seizure or serious neurologic dysfunction, and significant brain injury. Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1