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Maternal and Fetal Health Effects of Working during Pregnancy
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ABSTRACT

We provide some of the first empirical evidence of maternal and fetal health effects of working during pregnancy by using a unique dataset from the New Jersey Department of Health that includes information not only on pregnancy and birth outcomes but also on maternal employment. We match the mother's occupation with the Metabolic Equivalent of Task, provided by the Census Occupational Classification System and used as a measure for the strenuousness of the work activities performed. We find robust evidence that working in a relatively more strenuous job during pregnancy raises the likelihood of fetal macrosomia by about 1.5 percentage points. There are no statistically or economically significant effects on other birth outcomes. Our study further indicates an under-studied link between gestational diabetes (a known risk factor for fetal macrosomia) and intensive physical activities at work during pregnancy, potentially mediated by disrupted sleep due to greater work intensity.

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1. Introduction

Working during pregnancy has become increasingly common in the United States over the past four decades, with the share of women working at all while pregnant growing from 44% in 1968 to almost 70% in 2017.[4] While this increase coincided with the secular rise in women's overall workforce participation, other factors have also played a role in enabling more women to stay in the labor force during (and after) pregnancy (Laughlin 2011). Norms with respect to how families approach work and child rearing have shifted such that women are no longer expected to drop out of the labor force upon becoming pregnant. The Pregnancy Discrimination Act in 1978 prohibited discriminatory practices in hiring, firing, promotion or wages on the basis of pregnancy or childbirth. The 1980s witnessed the emergence of flexible work schedules and employer-based child care benefits, making it easier for women to continue working upon becoming pregnant and after giving birth. The Family and Medical Leave Act of 1993 mandated up to 12 weeks of unpaid leave for qualified medical or family reasons, including pregnancy and care of a newborn child.

Not only are more expectant mothers continuing to work, they are also working longer hours and further into their pregnancy. The share of women employed full-time (35 plus hours weekly) while pregnant increased from 31% to 50% over 1968–2017. Furthermore, the vast majority of working pregnant women, which is 82% in 2006–2008, continued to work up to one month or less prior to childbirth, up from only 35% during the early 1960s (Gao and Livingston 2015; Laughlin 2011). With more women continuing to work longer into their pregnancy and

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[4] Authors' calculations were based on data from the March Current Population Surveys (CPS). Pregnant women in the CPS are identified as women who have children under the age of one at the time of the survey (Dave et al. 2015). Using data from the U.S. Census Bureau's Survey of Income and Program Participation (SIPP), the U.S. Census Bureau reports a similar increase in work during pregnancy among first-time mothers, from 44.4% during the early 1960s to 69.2% during 2001–2005, declining somewhat to 65.6% over 2006–2008 as a result of the recession (Laughlin 2011).

being increasingly more exposed to conditions at work, it is important to understand how job attributes are affecting pregnancy outcomes. We provide some of the first empirical evidence of the effects of one important job attribute—the overall strenuousness of the job—on maternal and fetal health.

While the link between certain workplace hazards, notably occupational exposures to chemical compounds, and pregnancy outcomes is well-studied and generally well-established in the literature,[5] the risk for adverse pregnancy outcomes can also extend to more common occupational exposures such as the physical demands of the job. The threshold for physical exertion is lower for pregnant women, and work activities that would normally be considered moderate for non-pregnant women may prove to be more demanding during pregnancy.[6] Working during pregnancy is generally considered safe for most women with uncomplicated pregnancies, although special guidelines have been issued by the Centers for Disease Control and Prevention (CDC) and the American College of Obstetricians and Gynecologists with respect to jobs that have particular physical demands (e.g., heavy lifting, prolonged standing, or repeated bending).

Provision of accommodations at work for pregnant women who hold strenuous jobs is far from universal in the United States. As of June 2019, only 27 states and D.C. had enacted laws requiring some employers to provide reasonable accommodations for pregnant women.[7] If strenuous work activities are found to adversely impact maternal and fetal health, then resulting

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[5] See Jackson et al. (2018). Also see: https://www.cdc.gov/niosh/topics/repro/specificexposures.html (accessed in August 2019) and http://www.who.int/ceh/capacity/occupational.pdf (accessed in August 2019).

[6] The high demand for blood flow to the uterus and placenta can limit cardiac output and reserve capacity for vigorous activity levels (Bonzini, Coggon, and Palmer 2007).

[7] See: http://www.nationalpartnership.org/our-work/resources/workplace/pregnancy-discrimination/reasonable-accommodations-for-pregnant-workers-state-laws.pdf (accessed in August 2019). Protections offered by these laws also vary by state, for instance in some cases applying only to public employers, requiring documentation by a health care professional, or allowing for exemptions in the case of "undue hardship on the employer."

health benefits need to factor into any cost-benefit calculus surrounding the policy debate of whether to require employers to provide work accommodations for female workers during pregnancy.[8]

Our study broadly contributes to and bridges two strands of literature, one relating to how job conditions impact workers' health (Barnay 2016; Case and Deaton 2005; Gueorguieva et al. 2009; Kelly et al. 2014; Theorell 2000) and the other relating to how prenatal inputs affect maternal and infant health (Conway and Kutinova 2006; Corman, Dave, and Reichman 2018a & 2018b). Research on specific working conditions, activities, and pregnancy outcomes indicate some associations between certain physical activities and higher risks of adverse outcomes, such as preterm birth, although the evidence base is far from conclusive (Mozurkewich et al. 2000). Reviews of this literature have been understandably measured in their conclusions, acknowledging the uncertainty in the estimates and study designs as well as the lack of a sufficiently compelling evidence base to justify any mandatory restrictions on studied activities such as shift work, lifting, standing and heavy physical workload (Bonzoni, Coggon, and Palmer 2007; Mozurkewich et al. 2000; Palmer et al. 2013). Palmer et al. (2013) note, for instance, that while "small levels of excess risk may exist [with respect to these work activities]…it is also possible that much or all of these effects are explained by a combination of chance, bias and imperfectly controlled cofounding."

Our study adds to this limited evidence base and addresses several gaps in the existing literature. We utilize a unique dataset that includes information not only on pregnancy and birth outcomes but also on maternal employment and occupation during pregnancy. This allows us to

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[8] At the federal level, the Pregnant Workers Fairness Act, which among other protections ensures that employers provide reasonable accommodations to pregnant women who want to continue working, has been opposed every time it has been introduced (Pisko 2016). Part of the opposition stems from the stance that such requirements would impose an undue burden on businesses and raise business costs.

match objective external information on the overall physical demand of the job. Virtually all of the prior work has alternately relied on women's self-reports of their physical activities during pregnancy, at times conflating work-related and leisure-time activities. As recreational physical activity outside of work has been found to have stronger health-promoting effects relative to physical activity from one's own job (Saffer et al. 2013), and more intense job-related physical activity tends to crowd out recreational exercise and leisure-time activities (Colman and Dave 2013), conflating both work and non-work physical activities is potentially problematic.

Studies that have considered work activities per se have focused on mothers' reports of certain tasks in isolation (e.g., standing at work, lifting heavy loads, whether work involves high or low activity, whether work is mostly sedentary or requires physical effort) rather than the overall physical demand and strenuousness of the job. In addition to potential recall bias, which is a limitation highlighted by the reviews of this literature, self-reported work activity measures are also more likely to be plagued with selection bias.[9] For instance, pregnant women in physically demanding jobs may engage in compensatory behaviors and request accommodations for a less intensive workload if they have a preference for such or if they feel overly exerted.[10, 11]

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[9] Casas et al. (2015) do not specifically look at strenuousness or physical activity, but consider the effects of working in one of 14 occupational groups on birth outcomes, based on mother-child pairs across 13 European cohorts. Working in certain occupations was also associated with pregnancy outcomes. Specifically, they find that working as a nurse was associated with favorable birth outcomes, whereas working in the food industry reduced gestation and raised preterm births.

[10] This would impart a form of reverse causality from maternal or fetal health to reported work activity during pregnancy, and also cause the measure of work activity during pregnancy to be correlated with the error term of a regression model.

[11] Provision of accommodations by employers is not automatic or required in all cases. Under the Pregnancy Discrimination Act, an employer is required to provide certain accommodation such as altered break and work schedules, permission to sit or stand, ergonomic office furniture, shift changes, elimination of marginal job functions, and permission to work from home, if and only if accommodations have also been provided to other employees who have similar limitations that are not caused by pregnancy. A pregnant woman may also be able to obtain an accommodation at work, under the American with Disabilities Act (ADA), if and only if they have a pregnancy-related medical condition (for instance, anemia, sciatica, gestational diabetes, depression, and others) that meets the ADA definition of "disability." See: https://www.eeoc.gov/eeoc/publications/pregnant_workers.cfm (accessed in November 2018).

Our study provides some of the first empirical evidence on how the overall strenuousness of the type of job performed by a pregnant woman, as measured by the occupational Metabolic Equivalent of Task (MET), affects her health and her newborn's health. While we investigate standard birth outcomes, including gestational length, birth weight, and low birth weight, we also move beyond the literature and consider effects on maternal health indicators that may be particularly sensitive to pregnancy-related activity, including weight gain during pregnancy and gestational diabetes. We further shift the lens and consider the impact of job strenuousness on the upper tail of the birth weight distribution, and pinpoint important effects on fetal macrosomia, which is defined as birth weight exceeding 4,000 grams. We find robust evidence that, compared with light-intensity activity, moderate-intensity activity at work during pregnancy raises the likelihood of fetal macrosomia by about 1.5 percentage points, with gestational diabetes being one important biological channel. This focus on the upper tail of the birth weight distribution is important because it reveals an inadequacy in using birth weight alone as an outcome for the investigation of the adverse impact of job strenuousness during pregnancy: we find that compared with light-intensity activity, moderate-intensity activity at work during pregnancy, on average, raises the birth weight by nearly 40 grams, which can be driven by an increased risk of fetal macrosomia, and therefore should not be interpreted as a beneficial effect of having strenuous physical activities at work during pregnancy.

The rest of the paper proceeds as follows. Section 2 describes the conceptual framework, followed by the descriptions of our data and methodology in Section 3. We discuss the findings in Section 4 and conclude the paper in Section 5.

2. Conceptual Framework

The objective of this study is to assess how the physical intensity of jobs affects the health of pregnant women and their birth outcomes. This question can be described using a maternal health production framework, following Corman, Joyce, and Grossman (1987) and summarized in Corman, Dave, and Reichman (2018a). Maternal utility (U_m), expressed in equation (1) below, is a function of consumption goods that can be health-promoting ($C^{Healthy}$) or health-depreciating ($C^{Unhealthy}$), own health (H_m), infant health (H_i), and preferences (v_m).

$$U_m = U(C_m^{Healthy}, C_m^{Unhealthy}, H_i, H_m; v_m) \tag{1}$$

Infant health is produced (equation 2) using positive (e.g., exercise or nutrition) and negative (e.g., smoking or drug use) maternal consumption goods (C), other prenatal inputs such as medical care (D) and work conditions (J), as well as maternal time inputs (T). Infant health also depends on the health of the mother (as reflected in H_m), with E representing an efficiency parameter (typically proxied by maternal education) that modifies the marginal product of the other inputs (Grossman and Kaestner 1997). An analogous production process is defined for maternal health in equation (3).

$$H_i = f(C_m^{Healthy}, C_m^{Unhealthy}, D_m, J_m, T_m, H_m; E_m) \tag{2}$$

$$H_m = g(C_m^{Healthy}, C_m^{Unhealthy}, D_m, J_m, T_m; E_m) \tag{3}$$

Utility maximization occurs subject to the production constraints and the standard income and time constraints. We estimate reduced-form versions of these production functions, directly relating the intensity of the job (J) to indicators of maternal and fetal health (H_m and H_i). Job strenuousness can affect health in this framework, both directly and indirectly.

Direct effects of job strenuousness on maternal and infant health may operate through biological pathways. Ergonomic stressors, such as intense work activity, may affect the sympathetic nervous system and are associated with the release of prostaglandins, natural chemicals that play a role in the inflammatory process (Mozurekewich et al. 2010). Heavy physical exertion could increase uterine contractility and raise the risk of preterm birth, and can also reduce maternal-fetal blood flow (Juhl et al. 2013; Palmer et al. 2013). Physical and mental stress from fatigue, exertion, and intense activity is further known to increase levels of catecholamines, which have also been found to decrease uterine blood flow (Katz et al. 1991). Hormonal imbalance, including for stress hormones, is a risk factor for maternal gestational diabetes, which in turn can affect fetal health. A large literature has identified maternal stress during pregnancy as a significant predictor of adverse birth outcomes (Bussières et al. 2015).

Indirect effects of job strenuousness on maternal and fetal health can reflect behavioral pathways. For instance, stress and mental strain, which might be induced by intense work activity, have been found to increase addictive consumption (for instance, smoking and drinking), caffeine consumption, caloric intake, as well as unhealthy eating, and reduce vitamin use and exercise both for the overall population and particularly for pregnant women.[12] In the above framework, job strenuousness (J) can therefore affect H by impacting prenatal consumption and inputs, C and D.

More intense activity at work can also affect other time inputs (T), by further reducing the demand for recreational exercise and lowering physical activity outside of work (Colman and Dave 2013; Saffer et al. 2013). The net effect on caloric expenditure is unclear as the intensity of work activities is crowding out non-work activities. However, the overall shift in the composition of physical activity may be health-deteriorating, since moderate physical exercise

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[12] See, for instance, Dave and Kelly (2012), Hanna et al. (1994), Hauge et al. (2012), Lobel et al. (2008), and Saffer and Dave (2005). The link from stress to unhealthy eating and nutrition is not necessarily unidirectional. There is some evidence of complex interactions, wherein maternal psychosocial stress, dietary behavior, and nutrition likely regulate and counter-regulate one another during pregnancy (Lindsay et al. 2017). Much of this literature, specifically for pregnant women, captures associations and is hard-pressed to draw firmer conclusions regarding causality.

can have beneficial effects and is routinely recommended for women with uncomplicated pregnancies (American College of Obstetricians and Gynecologists 2015; Palmer et al. 2013).

More strenuous jobs can also affect time use patterns and disrupt sleep. Åkerstedt et al. (2002) find that high work demand and physical effort at work are associated with disturbed sleep. Martins et al. (2016) similarly report a higher prevalence of sleep disturbances and lower sleep quality among workers whose jobs involved high physical effort. Furthermore, Borodulin et al. (2010) specifically examine pregnant women and find reduced sleep duration to be correlated with increased level of occupational physical activity. Such changes could trigger neuroendocrine changes that affect fetal growth (Palmer et al. 2013). Furthermore, a recent study found that inadequate sleep among pregnant women may be a contributing factor towards the development of gestational diabetes, an outcome that we test in our study (Reutrakul et al. 2018). Gestational diabetes, in turn, raises birth weight and the likelihood of having a macrosomic birth, which is further associated with an increased risk of being overweight at adolescence (Gillman et al. 2003; Lawlor et al. 2010). Hence, effects on birth outcomes may also be mediated by maternal health, which is an input in the infant health production function (equation 2).

We use the conceptual framework discussed here to highlight plausible biological and behavioral channels that can influence how job strenuousness affects the mother and her baby during pregnancy, for which our study adds to the very limited evidence base and provides some of the first empirical estimates in the literature. Findings to date, albeit based on isolated and disparate self-assessed activity measures, have been mostly presented as associations due to potential bias from confounding and selection. We capitalize on a unique dataset containing detailed information on the mother's occupation, in addition to her various pre-pregnancy characteristics and residential location, which allows us to indirectly assess the extent to which our results may be driven by non-random selection into work.

3. Empirical Framework

3.1. Data

Our birth data come from the New Jersey Department of Health (NJDOH), covering live births that occurred in New Jersey. These data include information on the newborn such as birth weight and gestational length, as well as information on the mother, regarding demographic characteristics and health, such as body weight prior to pregnancy, weight gain during pregnancy, and gestational diabetes. Our study uses the NJDOH's birth records of years 2014 and 2015 because in those two years and for a randomly selected subset (approximately 36% of the birth records), the NJDOH collected additional information on the mother's occupation and whether the mother worked in the year prior to childbirth. Hereafter, we refer to this subset with the additional information collected as the "NJDOH subset." Because our study focuses on job strenuousness during pregnancy, we include into our estimation sample only mothers who worked in the year prior to childbirth, which constitute about 64% of the NJDOH subset's records. In our estimation sample all mothers live in New Jersey (about 97% of the NJDOH subset's records), and all births are singleton births (about 96% of the NJDOH subset's records). We focus on singleton births, to avoid cases where adverse birth outcomes occur specifically because of carrying multiple fetuses in a single pregnancy.

To the best of our knowledge, our dataset so far has been the only one that contains information on both birth outcomes and maternal occupation. However, the entry of the information on maternal occupation was not standardized and was recorded only in words. We examined all of these verbal descriptions in the birth records and then assigned each of them a Census 2002 Occupation Code, which is a four-digit code.[13] In the end, 330 unique occupation codes were applied to the NJDOH subset. Next, we linked each Census 2002 Occupation Code to a MET value, with the linkage being defined by the 2002 Census Occupational Classification System.[14] MET values are designed to reflect and increase with the intensity and strenuousness of physical activities. A unit of MET is defined as the ratio of a person's working metabolic rate relative to his or her resting metabolic rate. Thus, one MET is defined as the energy it takes to sit quietly, and a MET of 1.5 is associated with typing or writing performed at a desk.[15]

We follow the epidemiology literature to group MET values into three categories: 1) light-intensity activities, with MET < 3, including activities such as sitting (e.g., using computer or fishing) and standing with light work (e.g., cooking or washing dishes); 2) moderate-intensity activities, with $3 \leq \text{MET} \leq 6$, including activities such as walking (e.g., very brisk walk at a speed of 4 mph) and heavy cleaning (e.g., vacuuming or mopping); and 3) vigorous-intensity activities, with MET > 6, including activities such as basketball game and tennis (singles).[16] In our study we focus on the comparison between moderate-intensity and light-intensity activities, since 99% of our birth records have MET values of maternal occupations between 1.5 and 4, and only two birth records have MET values that are greater than 6.

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[13] For details about the Census 2002 Occupation Codes, please see https://www.bls.gov/tus/census02iocodes.pdf (pp. 7–17, accessed in April 2018).

[14] For details, see https://epi.grants.cancer.gov/physical/MET under the section titled "MET Values for Activities in the 2002 Census Occupational Classification System (OCS)" (accessed in April 2018). We gave two examples here: (1) For descriptions entered in the data such as "housing keeping", "house cleaning", "housekeeping", "cleaning person", "cleaning lady", "cleaning houses", and "merry maids", we converted them to the occupation code 4230 ("Maids and housekeeping cleaners") and the occupation code 4230 is linked to a MET value of 4.5; (2) For descriptions entered in the data such as "administrative assistant", "admin assistant", "admin asst", and "secretary", we converted them to the occupation code 5700 ("Secretaries and administrative assistants") and the occupation code 5700 is linked to a MET value of 1.5.

[15] For the average adult, one MET represents about one calorie per every 2.2 pounds of bodyweight per hour.

[16] For more details, see https://www.hsph.harvard.edu/nutritionsource/mets-activity-table (accessed in April 2018).

We further match a set of variables capturing the socio-economic and demographic composition of the mother's residential area. These include total population, population by race and ethnicity (White, Black, and Hispanic), number of households, average household size, average housing value, household income, and median age at the zip code level.

Table 1 reports the summary statistics of variables related to MET, variables related to pregnancy and birth, variables related to the mother, and variables related to the mother's residential characteristics at the zip code level.[17] The summary statistics are reported for each of the three cases: estimation sample including only cases of light-intensity activity at work, estimation sample including only cases of moderate-intensity activity at work, and the full estimation sample. Overall, women who engaged in moderate-intensity activity at work during pregnancy, compared with those who had light-intensity activity at work during pregnancy, appear to be younger, less likely to be White, more likely to be Black (or Hispanic), less likely to complete a four-year college or higher, less likely to be married, less likely to have private insurance, more likely to have Medicaid, more likely to smoke, living in zip codes with lower average housing values, and living in zip codes with lower average annual household income; in addition, they also have heavier body weight, or higher body mass index (BMI), prior to pregnancy. In the full estimation sample, the rate of fetal macrosomia (defined as birth weight > 4,000 grams) among singleton births that occurred in New Jersey between 2014 and 2015—8.6%—is similar to the U.S. singleton fetal macrosomia rate during that period, which is 8.3%.

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[17] We purchased a zip code database from https://www.zip-codes.com/zip-code-statistics.asp. This database provides the following zip code-level variables: the population size for each zip code based on the 2010 U.S. Census and the associated White, Black and Hispanic subpopulation sizes for that zip code, the number of households for each zip code based on the 2010 U.S. Census, the average number of individuals per household for each zip code based on the 2010 U.S. Census, the average house value for each zip code based on the American Community Survey five-year estimate, the average household income for each zip code based on the American Community Survey five-year estimate, and the median age among all individuals for each zip code based on the 2010 U.S. Census.

In the full estimation sample, we also see the rates of LBW (low birth weight, defined by birth weight < 2,500 grams) and preterm birth (defined by gestational length < 37 weeks) are 5.2% and 7.0%, respectively. Both rates are below the corresponding U.S. averages among singleton births—6.3% for LBW and 9.6% for preterm birth.[18] The lower rates of LBW and preterm birth in New Jersey are reasonable, given that New Jersey is a relatively more wealthy state,[19] and higher income tends to correlate with fewer adverse birth outcomes (such as LBW and preterm births), possibly due to better access to or greater utilization of health care.

3.2. Methodology

The regression model for our main analysis is specified as follows and can be interpreted as a reduced-form production function of infant health:

$$y_{icjmt} = \alpha_0 + \alpha_1 d_c + \boldsymbol{x}'_{icjmt}\beta + \gamma_j + \delta_k + \eta_{mt} + \epsilon_{icjmt} \quad (4)$$

In this equation y_{icjmt} denotes the birth outcome (e.g., fetal macrosomia) of an infant born in month *m* during year *t*, to mother *i* working in occupation *c* and living in zip code *j* during her pregnancy. The variable *d* is binary, equal to one for moderate-intensity activity (i.e., $3 \leq \text{MET} \leq 6$) and equal to zero for light-intensity activity (i.e., MET < 3). In alternate specifications we also assess the effects of a continuous measure of work intensity as measured by the MET value for the occupation. The vector denoted ***x*** includes the following variables: the sex of the baby; the mother's age, race and ethnicity, educational attainment, marital status, health insurance status during pregnancy, prenatal care utilization, parity, whether or not having previous preterm birth, and smoking status. The zip code fixed effect (γ_j) captures the time-invariant socio-

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[18] The U.S. rates of LBW, preterm birth, and fetal macrosomia among singleton births averaged over 2014 and 2015 were all obtained from the CDC WONDER Online Database (https://wonder.cdc.gov/natality.html, accessed on August 13, 2017).

[19] In our estimation sample, the average annual household income measured at the zip code level is approximately $75,300 (shown in Table 1).

economic and demographic characteristics of the mother's zip code of residence. Also included in the regression model are year-by-month of birth fixed effects (η_{mt}), to account for any seasonality in fertility and births as well as common shocks affecting mothers over the sample period.[20] We estimate the regression model using ordinary least squares (OLS) with standard errors clustered at the mother's residential zip code level.

In our study the use of an occupation-specific measure of work intensity bypasses some of the endogeneity concerns that plagued earlier studies relying on self-reported measures of workload or activity. For instance, women may sort non-randomly into jobs with varying levels of physical activity within an occupation, or pregnant women who are particularly at risk could shift jobs or request special accommodations.[21] The occupation-specific measure of work intensity avoids these selection issues since it is not specific to a particular pregnant woman's situation. However, there is still the possibility of non-random selection in occupational choice. To address this possibility, we include maternal occupation fixed effects (δ_k). Regarding this fixed effect, we are unable to apply it to every occupation code because each occupation code is assigned a unique MET value according to the Census Occupational Classification System, which results in no variation in MET *within* each occupation code. Therefore, we apply the occupation fixed effects based on the 22 occupational groupings as categorized under the 2002 Census Occupational Classification System.[22] In our regression models we further include area

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[20] An identifier for each mother is unobserved in our birth data. As a result, we are unable to add mother fixed effects to our regression model.

[21] In New Jersey, all employers are required to provide reasonable accommodations to pregnant women, women who have given birth or women affected by related medical conditions, if such accommodation is requested by the worker based on physician advice, unless doing so would impose an undue burden on the employer (source: http://www.nationalpartnership.org/our-work/resources/workplace/pregnancy-discrimination/reasonable-accommodations-for-pregnant-workers-state-laws.pdf, accessed in August 2019).

[22] The 22 groups are: management; business and financial operations; computer and mathematical; architecture and engineering; life, physical, and social science; community and social services; legal; education, training, and library; arts, design, entertainment, sports, media; healthcare practitioner and technical; healthcare support; protective service; food preparation and serving related; building and grounds cleaning and maintenance; personal care and

fixed effects, alternately at the county level or at the five-digit zip code level, to control for unobserved time-invariant (over 2014 and 2015) area-specific factors, such as local infrastructure, built environment, and access to health care. The identifying assumption is that after controlling for mother's observed demographic characteristics, area fixed effects (in particular, the zip code fixed effects) and within those occupational categories, physical intensity at work, which is related to occupation choice, is unrelated to unobserved maternal characteristics.

We evaluate the plausibility of this assumption in Table 2 through the comparisons of maternal demographic characteristics between those who had moderate-intensity activity at work (the "treated" group) and those who had light-intensity activity at work (the "control" group). Comparing columns (1) through (4), we see that controlling for mother's residential zip code fixed effects (column 2 compared with column 1) and controlling for mother's occupation dummy variables (column 3 compared with column 2) reduce the magnitude of the difference in the observed maternal demographic characteristics between the "treated" group and the "control" group. Besides, in column (4) where we also control for individual level demographic variables, the magnitude of the difference in the observed maternal demographic characteristics between the two groups is further reduced; in particular, in cases such as maternal education, whether having previous preterm birth (related to maternal health), whether having private health insurance, and whether having Medicaid (related to maternal income), the differences between the "treated" group and the "control" group are statistically insignificantly different from zero. Results reported in Table 2 are certainly not a definitive test of the aforementioned identifying

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service; sales and related; office and administrative support; farming, fishing, and forestry; construction and extraction; installation, maintenance, and repair; production; and transportation and material moving. For details, see "MET values for activities in 2002 Census Occupational Classification System (OCS)" at https://epi.grants.cancer.gov/physical/MET/#ocs, accessed in April 2018).

assumption. Nevertheless, those results are reassuring in the sense that controlling for residential zip code fixed effects and maternal occupation fixed effects, in addition to the conventional set of maternal demographic variables (such as age, race and ethnicity, education, marital status, parity, and health insurance status), help mitigate the bias (in estimating the effect of having moderate-intensity activity at work) that comes from selection on unobservables. In Section 4.3, we give further discussions on assessing the impact of selection on unobservables, using the method proposed by Oster (2019).

In our robustness checks we also add controls for whether the mother's residence and workplace are in the same county, and alternately the same zip code. By doing so, we assess the impact of residential sorting, which may be correlated with access to jobs, proximity to work, occupational choice and health. Furthermore, we add controls for job attributes and labor supply behaviors, using data from the American Community Surveys (ACS). These control variables help us evaluate the potential bias from omitting variables that are correlated with job strenuousness and fetal (or maternal) health. However, because the ACS data and NJDOH data are not perfectly matched, we view the results with these control variables as suggestive.

We capitalize on the richness of the NJDOH data, which contain information on several maternal characteristics prior to pregnancy, by adding measures of pre-pregnancy maternal health, including body weight, BMI, diabetes, and whether the mother had a previous preterm birth. As indicators of baseline maternal health endowment, these measures are potentially correlated with both pregnancy outcomes as well as occupational choice. To the extent that strenuous jobs may have cumulative effects on reproductive health, controlling for the mother's baseline health endowment also serves to disentangle the effects of work intensity during pregnancy per se. Pre-pregnancy outcomes, notably maternal diabetes prior to pregnancy, further permit a placebo check. While work intensity during pregnancy can plausibly affect gestational diabetes, we would not expect the strenuousness of the mother's job during pregnancy to have any impact on her diabetes status prior to pregnancy.

To the extent that the data allow, we also investigate biological mechanisms operating through maternal heath during pregnancy. Specifically, we explore how job strenuousness affects maternal weight gain during pregnancy and gestational diabetes, and the extent to which these directly mediate any effects on fetal health. Finally, for outcomes where we find robust effects, we examine heterogeneity by the infant's sex, parity, and maternal characteristics (education, race, and marital status).

4. Results

4.1. Main Results

In Table 3 we assess the effects of job strenuousness on standard birth outcomes. Panel A reports the results based on the dummy variable d in equation (4). Panel B reports the results of replacing that dummy variable with the continuous measures of the MET. In odd-numbered columns we control for mother's residential county fixed effects and zip code level characteristics (reported in Table 1, such as population size and average household income). In even-numbered columns we saturate the models with mother's residential zip code fixed effects, which is our preferred specification. In all columns we control for mother's pre-pregnancy BMI.[23]

Overall, with our preferred specifications (in even-numbered columns), we find little evidence that greater intensity of work activities during pregnancy is associated with LBW,

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[23] The estimates remain very similar whether we control for mother's pre-pregnancy BMI or mother's body weight prior to pregnancy.

gestational length or preterm birth, whether we use the dummy variable *d* in equation (4) or the continuous measure of the MET. This result may partly reflect our focus on women who worked during pregnancy (which is our estimation sample), a group that is on average healthier and at a lower risk of LBW or preterm birth than those who did not work.[24] In the case for birth weight, we find that intensive activities at work during pregnancy appear to be linked to increased average birth weight (columns 1 and 2 of Panel A). This finding appears to be driven by the upper tail of the birth weight distribution, that is, a greater risk of fetal macrosomia among pregnant women who engaged in more intensive activities at work (columns 3 and 4 of Panel A).

Specifically, we find that, compared with light-intensity activity, moderate-intensity activity at work during pregnancy is associated with an increase of 1.9 percentage points in the likelihood of fetal macrosomia. The estimates remain similar, whether using mother’s residential zip code fixed effects (column 4) or using mother’s residential county fixed effects plus controlling for residential zip code-level characteristics (column 3). These results suggest that the zip code-level control variables used in our regression analysis adequately captured zip code-level time-invariant heterogeneities that are unobservable to us. Estimates in Panel B (columns 3 and 4) are qualitatively the same as the results reported in Panel A (columns 3 and 4). Engaging in work with an additional intensity of one MET is associated with about a one percentage-point increase in the likelihood of fetal macrosomia. Given that the average difference between moderate intensity and light intensity work amounts to about 1.3 MET’s on average (Table 1), these estimates imply a 1.3 percentage-point increase in the likelihood of fetal macrosomia among pregnant women working in moderate intensity jobs.

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[24] Casas et al. (2015) find that employed pregnant women had a significantly lower risk of having a preterm birth relative to those who were non-employed. In our birth data we also find that the birth weight and gestational length of babies born to mothers who worked during pregnancy are both slightly greater than those of babies born to mothers who did not work during pregnancy.

4.2. Robustness Checks

Estimates in Table 3 suggest that prenatal employment in more strenuous jobs raises birth weight at the upper tail of the distribution, thus leading to a higher probability of fetal macrosomia. We do not find any evidence of statistically or economically significant effects on low birth weight or on gestational length. In Tables 4 and 5, we therefore focus on the effects on fetal macrosomia, and conduct a series of checks to assess the plausibility of this finding.

The most inclusive specification used in column 4 of Table 4 is the same one used in column 4 (Panel A) of Table 3, which we view as our preferred specification. This specification includes covariates that proxy for unobserved maternal health endowment and other sources of heterogeneity, but could also constitute channels through which job attributes may affect maternal and fetal health. Columns 1 through 3 of Table 4 report estimates from models that alternately omit variables related to the mother's insurance status during pregnancy (column 1), whether the mother had a previous preterm birth, which is used as a proxy for unobserved mother's health status causing adverse birth outcomes (column 2), and the mother's smoking status (column 3).[25] Estimates reported in columns 1 through 4 are very similar. This pattern suggests that our finding of the greater risk of fetal macrosomia is unlikely to operate through channels related to health insurance, maternal risk factors related to having previous preterm births, or maternal risky behaviors such as smoking. Furthermore, the robustness of our results provides some degree of validation that, within occupation categories, relatively higher intensity of work activity is not conflating the effects of low socioeconomic status; note that, if anything,

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[25] In the New Jersey birth data the variable on the mother's smoking status is binary (1/0), which is equal to one (or zero) for a yes (or no) answer to this question: "Did mother smoke cigarettes before or during Pregnancy?" As a result, this variable on the mother's smoking status can capture the mother's smoking behavior during three periods: before pregnancy, during pregnancy, and up until childbirth.

the unconditional differences in Table 1 go in the opposite direction and show that the prevalence of macrosomia is lower among those with relatively more physically-demanding jobs.

In Table 4 it is notable that the R-squared remains the same except in column (2), where we drop the variable on whether the mother had a previous preterm birth. This pattern suggests that with respect to fetal macrosomia, mother's health status, partly captured by whether the mother had a previous preterm birth, is an important explanatory variable.[26] In contrast, the R-squared stays the same when adding the variables on the mother's insurance status and the mother's smoking status. This result suggests that mother's insurance status and mother's smoking status, although important for improving fetal health, have little explanatory power for this specific outcome variable—fetal macrosomia.[27]

While the results in Table 4 are validating and suggestive that our estimate of the effect of having moderate-intensity activity at work during pregnancy on fetal macrosomia might not be biased due to the omission of variables related to work benefits (e.g., providing health insurance) even if there is selection into occupation based on those work benefits, the concern remains that these pregnant women with relatively more strenuous work may also differ with respect to other job attributes and the labor supply behaviors. We assess this possibility more directly in Table 5. Specifically, in Table 5 we utilize the information regarding maternal employment in the birth data to include fixed effects regarding the mother's employer's location (columns 1 and 2) and fixed effects regarding the geographic distance between the mother's home and her employer (columns 3 and 4).[28] Compared with the results in Table 3 (column 4 of

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[26] In the regression model used by column (4) of Table 4, the coefficient of this regressor—whether the mother had a previous preterm birth—is highly statistically significant (*p*-value = 2.159×10^{-6}).

[27] In the regression model used by column (4) of Table 4, the coefficients of these regressors—whether the mother had private insurance during pregnancy, whether the mother had Medicaid during pregnancy, and whether the mother smoked cigarettes before or during pregnancy—are all statistically insignificant.

[28] In our estimation sample all mothers live in New Jersey, and their employers are located in New Jersey (86.96%), New York (8.51%) and Pennsylvania (4.53%).

Panel A), the estimates reported in Table 5 are somewhat smaller,[29] after we control for the mother's employer's county fixed effect (column 1), the mother's employer's zip code fixed effect (column 2), or the mother's home and employer being in the same county (column 3) or being in the same zip code (column 4). Hence, factors related to the geographic areas of the mothers' employers appear to be positively correlated with the intensity of the physical activity at work and with the risk of fetal macrosomia. The coefficient magnitudes (columns 1 through 4) indicate about a 1.5 percentage-point increase in the likelihood of fetal macrosomia (about 17% relative to the sample mean, which is 8.6% reported in Table 1). The similarity in the estimates between columns 3–4 and columns 1–2 suggests that those aforementioned possibly omitted factors could be related to maternal travel distance between home and workplace. Indeed, in a regression model in which we control for the travel distance between the mother's home and the mother's workplace, the estimated coefficient for "moderate-intensity activity at work (1) vs. light-intensity activity at work (0)" is 0.0152 (statistically significant at 10%, with *p*-value equal to 0.069), which is very similar to the magnitude (around 0.015–0.016) reported in Table 5 (columns 1 through 4). However, the coefficient for the travel distance variable is not statistically significant, suggesting that it is not the travel distance itself, but other factors that are related to the travel distance, such as sleep deprivation, which could result from greater intensity of physical activities and also cause gestational diabetes leading to fetal macrosomia, that may account for the reduction in the estimate from 1.9 percentage points (in column 4 and Panel A of Table 3) to about 1.5 to 1.6 percentage points (in columns 1 through 4 of Table 5).

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[29] The sample size in Table 5 is smaller than that in Table 3 because of missing values for mothers' employers' counties or zip codes (columns 1 through 4) and also because of the merge with the ACS data (columns 5 through 8); standard errors in Table 5 are larger, compared with the standard errors in column 4 (Panel A) of Table 3.

While the NJDOH data are unique in allowing us to observe whether the mother worked during pregnancy and her occupation, they do not contain information on work hours, income, and other attributes, which may be potentially correlated with the job strenuousness. We therefore turn to the 2010–2017 ACS data to construct key labor supply measures for pregnant women residing in New Jersey and who worked during their pregnancy.[30] Specifically, we compute the means of the following variables by occupation, race/ethnicity, marital status, educational attainment (college vs. less than college), and age group (ages 16–30 and ages 31–50): weekly hours worked; annual wage income; prevalence of commuting to work by car, public transportation, or by other means (bicycle, walking, taxi, or other); and the prevalence of being able to work from home. We then match these to the NJDOH records by these socio-demographic cells.[31] Columns (5) through (8) of Table 5 presents estimates from the models used in columns 1 through 4 (including the employer's location) and now augmented with these other job attributes and labor supply measures. While standard errors become larger (likely due to loss in sample size), raising *p*-values (*p*-value ≈ 0.11 to 0.12) above the conventional significance thresholds, it is validating that the coefficient magnitudes remain similar to those reported in columns 1 through 4. Overall, results in Table 5 suggest that the effect of job strenuousness does not appear to be picking up other heterogeneity related to job attributes and labor supply behaviors.[32]

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[30] The ACS has information on whether the woman gave birth in the past 12 months, and a separate question on the ages of biological children in the household. These can be used to identify women who were pregnant and gave birth in the past year, along with labor market outcomes over this reference period to impute women who were working during their pregnancy year.

[31] Ideally, we would want to use the 2014–2015 ACS data to merge with the 2014–2015 NJDOH data. However, doing so makes the socio-demographic cells become too small. To ensure an adequate sample size after merging the ACS data with the NJDOH data, we use the ACS data from 2010 to 2017.

[32] In a meta-analysis Mozurkewich et al. (2000) find no statistically significant association between long working hours and adverse birth outcomes (e.g., preterm births), implying that omitting work hours may not lead to bias in models of birth outcomes.

4.3. Pathways

We further explore possible biological mechanisms through which higher intensity of physical activities at work is associated with greater risk of fetal macrosomia. Results are reported in Tables 6 and 7.

Results in Table 6 (columns 2 and 3) show that maternal weight gain during pregnancy,[33] including excessive weight gain,[34] and gestational diabetes are strong predictors of fetal macrosomia, which is consistent with the medical literature. Comparing the magnitudes of the marginal effects between column (1)[35] and columns (2)–(3), it appears that pathways operating through gestational diabetes and weight gain during pregnancy can account for at most one-third of the impact of work intensity on macrosomia.[36]

In Table 7 (columns 1 and 2), we find that moderate-intensity activity at work during pregnancy is associated with greater risk of gestational diabetes.[37] This finding is consistent with the summary statistics reported in Table 1: the prevalence of gestational diabetes is higher among pregnant women who had moderate-intensity activity at work (7.8%) than among those who had light-intensity activity at work (6.7%). In Table 7 (columns 1 and 2) we also find,

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[33] Weight gain is measured as the difference between body weight at delivery and pre-pregnancy body weight during pregnancy. The average weight gain in our estimation sample is about 30 pounds and the standard deviation is about 15 pounds. To avoid the influence of outliers in our estimation, we dropped from our estimation sample weight gain that is below zero or above 60 pounds, that is, two standard deviations away from the mean.

[34] The definition of mother gaining too much weight during pregnancy (1/0) is given by the Institute of Medicine Weight Gain Recommendations for Pregnancy (available at https://www.acog.org/Clinical-Guidance-and-Publications/Committee-Opinions/Committee-on-Obstetric-Practice/Weight-Gain-During-Pregnancy, accessed in April 2018), which gives a recommended range of weight gain specific to the mother's pre-pregnancy body weight category (underweight, normal weight, overweight, and obese).

[35] Results in column (1) of Table 6 are from column (4) of Table 3, included in Table 6 for comparison purpose.

[36] Comparing the results of columns (2)–(3) between Panels A and B, we find that it is the MET exceeding a certain threshold (Panel A), not the MET itself (Panel B), that is significantly associated with a greater risk of fetal macrosomia, even after controlling for weight gain and gestational diabetes. This points to possible nonlinearities in the effect of maternal job strenuousness during pregnancy on fetal health, for instance, when the strenuousness exceeds a threshold, such as a MET of three, which is the lower bound used in the definition of moderate-intensity activity.

[37] Results in Table 6 are suggestive since gestational diabetes and weight gain are endogenous mediators and constitute "bad controls" in the parlance of Angrist and Pischke (2009). Thus, we also use gestational diabetes and weight gain as outcome variables.

similar to the pattern revealed in Table 6 (columns 2 and 3), that it is the MET exceeding a certain threshold (Panel A), not the MET itself (Panel B), that is associated with a greater risk of gestational diabetes. Like the case of fetal macrosomia, the effect of maternal job strenuousness during pregnancy on gestational diabetes appears to be nonlinear and may not materialize until the strenuousness exceeds some threshold.

In contrast, regarding body weight we find that it is the MET, not the MET exceeding the threshold of three, that is associated with gaining too much weight during pregnancy (column 5 and Panel B of Table 7). This result, together with the results reported in Table 6 (column 3), suggests that the effect of an average level of maternal job strenuousness during pregnancy on fetal macrosomia could largely operate through maternal weight gain, specifically through gaining too much weight, but the job strenuousness has an additional nonlinear effect on fetal macrosomia, which becomes salient when the strenuousness exceeds a certain threshold (e.g., a MET of three). Results in Table 7 (columns 3 and 4) also suggest that the average weight gain is strongly associated with pre-pregnancy BMI, but not definitively related to MET (or MET exceeding the threshold of three). We also view the link between excessive weight gain during pregnancy and MET as inconclusive, since the association between the two becomes statistically insignificant once we replace mother's residential county fixed effects with zip code fixed effects (column 5 vs. column 6 of Panel B).

Taken together, these results suggest that our findings are consistent with the existing medical literature by showing that maternal weight gain during pregnancy and gestational diabetes are two risk factors for fetal macrosomia, and also unique in identifying job strenuousness during pregnancy as an independent risk factor for fetal macrosomia, adding to the existing literature. One possible causal chain underlying this finding is sleep-deprivation-induced diabetes (unmeasured or undiagnosed in our birth data), which can lead to fetal macrosomia. Strenuous work has been found to correlate with stress and sleep deprivation (Åkerstedt et al. 2002; Borodulin et al. 2010; Martins et al. 2016), [38, 39] and sleep deprivation has been found to correlate with diabetes (Barone and Menna-Barreto 2011; Van Cauter et al. 2008).

Although data limitations preclude direct assessment of the causal chain described above, such as data on sleep deprivation, we conducted a falsification check (see Table 8), to assess the validity of our preferred model. Specifically, we estimated the effect of maternal job strenuousness during pregnancy on pre-pregnancy diabetes, which is known to be zero. If we find any economically or statistically significant effects on pre-pregnancy diabetes, these would point to unobserved selection bias. Results in Table 8 reassuringly show that the estimates (in both Panels A and B) are statistically insignificant and close to zero in magnitude.

We assess heterogeneity in the effects of job strenuousness during pregnancy on fetal macrosomia in models reported in Table 9. These estimates suggest that the effect is more salient among male infants, which is consistent with the "fragile male" hypothesis in medical literature. We also find suggestive evidence of the effects being more concentrated among mothers who are African American (*p*-value = 0.108) or unmarried. In addition, the effects appear to be greater among mothers who have completed a four-year college or higher (i.e., those who are presumably of higher socioeconomic status). This may be explained by the fact that

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[38] Stress and sleep disturbances can go hand in hand, both being affected by job strenuousness. Once controlling for physical exertion entailed in a job, however, Homer, James and Siegel (1990) do not find occupational psychological stress to be independently associated with adverse birth outcomes.

[39] We conducted analyses with the American Time Use Surveys (2003–2018) to assess the link between job strenuousness, as measured in this study, and sleep. Consistent with the findings of these other papers, we also find that less sleep (measured by reduced sleep time) is significantly associated with working in more intense jobs (measured by higher MET values) among females aged 18–40, based on a regression model that controls for total time spent working on jobs, demographic characteristics (e.g., age, education, race and ethnicity), and county of residence and time effects (e.g., day, month, year and holiday).

mothers who have a college degree or higher are more likely to work during pregnancy than women have less education (Laughlin 2011).

Finally, we evaluate the potential impact of selection on unobservables, using the method proposed by Oster (2019). Specifically, we assess whether our estimate of the effect of having moderate-intensity activity at work during pregnancy on fetal macrosomia (0.0192, reported in column 4 and Panel A of Table 3) is robust to selection on unobservables, once we control for mother's residential zip code effects and occupation fixed effects. The results of this evaluation are summarized and reported in Figure 1. The maximal R-squared is obtained from a hypothetical regression in which both observables and unobservables that affect the treatment status and also the outcome of interest are included. In theory, this maximal R-squared can reach one if the outcome is measured perfectly, without any measurement error, and all contributing factors (either observed or unobserved) have been identified and included in the regression model. In reality, however, this maximal R-squared will not reach one in the presence of measurement error in the outcome or in the absence of perfect knowledge about the data generating process. As a result, choosing a specific maximal R-squared, which is required in Oster's method, is subjective and must be guided with empirical regularity. With our data, the bias-adjusted estimate, which is the estimate with selection on unobservables taken into account (calculated using Oster's method), starts to become implausibly large (0.1026, implying a more than 100% increase in the likelihood of fetal macrosomia, relative to its average rate) when the maximal R-squared approaches 0.069 (shown in Panel A of Figure 1). Therefore, we view the range of the maximal R-squared above 0.05 and below 0.069 as being consistent with empirical regularity. According to Oster (2019), assuming selection on unobservables is as important as selection on observables and if the bias-adjusted estimate falls within the confidence interval of the original estimated effect (0.019), then it suggests that the original estimate could be robust to selection on unobservables. Results reported in Panel A of Figure 1 suggests that in the range between 0.05 and 0.061 of the maximal R-squared, the estimate of the effect (0.019) could be viewed as robust to selection on unobservables. Note that the R-squared in the regression model not controlling for mother's zip code fixed effect and occupation fixed effect is about 0.03, and it increases to 0.05 by about 67%, once the model controls for those fixed effects. Results in Panel A of Figure 1 also suggest that the estimate of the effect (0.019) could be robust to the inclusion of unobservables into the regression model that raises the R-squared from 0.05 to 0.061 (by 22%).

We conducted another evaluation proposed by Oster (2019) and reported the results in Panel B of Figure 1. Here, we examined the relative importance of selection on unobservables compared with selection on observables, referred to as the coefficient of proportionality.[40] These coefficients reported in Panel B (as a function of the maximal R-squared) show how large selection on unobservables has to be in order for unobserved selection to be able to fully explain the observed effect of having moderate-intensity activity at work on fetal macrosomia. The estimated treatment effect (0.019) could be viewed as robust if the coefficient of proportionality exceeds one. As we previously discussed, the range of the maximal R-squared above 0.05 and below 0.069 could be viewed as being consistent with empirical regularity, and within this range, Panel B of Figure 1 shows that all coefficients of proportionality are substantially greater than one. This indicates that our estimated impact of engaging in a relatively more strenuous job during pregnancy could be viewed as robust to selection on unobservables; selection on

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[40] In Oster (2019), the coefficient of proportionality is referred to as "delta," which is the ratio of selection on unobservables divided by selection on observables. In Oster (2019), selection on observables (or unobservables) is characterized by the covariance between the (binary) treatment dummy variable and the observables (or unobservables).

unobservables would need to be several orders of magnitude greater than the selection on observables to be able to fully drive the results.

5. Conclusion

In this study we provide some of the first evidence of the impact of overall job strenuousness on maternal and fetal health. In doing so, we contribute to and bridge two strands of literature, one on how job conditions impact workers' health, and the other on how prenatal inputs affect maternal and infant health. The focus on the intensity of physical activity at work during pregnancy inevitably requires us to restrict the sample to women who worked during pregnancy. With this selected sample, we are unable to generalize our findings to all women. Nevertheless, the sample we focused on is of important policy interest, in light of a significant and continuing increase in the share of women working during pregnancy. Data from the CPS and the SIPP (Laughlin 2011) show that in 2017 almost 70% of women work at some point during their pregnancy.

Given that more pregnant women are working today, and working longer into their pregnancy, it is critical to understand the maternal and fetal health implications of work-related exposures. While the focus on hazardous exposures such as pollution and chemicals is important, these exposures are relatively rare, especially in comparison with job strenuousness, which can happen on a regular basis and cumulatively can result in a significant impact. In this regard, we utilize a unique dataset from the NJDOH, which contains information not only on pregnancy and birth outcomes but also on maternal employment during pregnancy. This dataset allows us to provide some of the first evidence in the literature regarding how the overall strenuousness of the type of job performed by a pregnant woman, as measured by the occupational MET, affects her and her newborn's health.

While we generally do not find adverse effects on the lower tail of the birth weight distribution, we find consistent evidence showing a robust association between job strenuousness during pregnancy and the risk of fetal macrosomia. Our finding on fetal macrosomia has important public health implications since a macrosomic birth is associated with not only a higher risk of being overweight at adolescence (Gillman et al. 2003; Lawlor et al. 2010) for the child, but also a higher risk of having breast cancer for the mother (Bukowski et al. 2012). Compared with light-intensity activity, our findings suggest that moderate-intensity activity at work during pregnancy is associated with an increase in the likelihood of fetal macrosomia of about 1.5 percentage points. Further checks confirm that our findings are not only consistent with the existing literature by showing that maternal weight gain during pregnancy and gestational diabetes are two risk factors for fetal macrosomia, but also unique in singling out job strenuousness during pregnancy as an independent risk factor for fetal macrosomia, after controlling for pregnancy weight gain and diagnosed gestational diabetes.

One possible mechanism underlying this finding is sleep-deprivation-induced diabetes (which is unmeasured or undiagnosed in our birth data), with gestational diabetes leading to fetal macrosomia. There is some evidence suggesting an adverse effect of strenuous activities at work on sleep quality (Åkerstedt et al. 2002; Borodulin et al. 2010; Martins et al. 2016), although physical exercises in general are often recommended to pregnant women for health benefits. Sleep deprivation has been found to correlate with diabetes (Barone and Menna-Barreto 2011; Van Cauter et al. 2008).

The uniqueness and richness of the NJDOH data allow us to use a large set of control variables and fixed effects, in an effort to address the endogeneity problem associated with the maternal job strenuousness during pregnancy, which can be caused by residential sorting, non-random selection in occupational choice, and the unobserved heterogeneity in maternal health. Regarding fetal macrosomia, it is notable that the diagnosis can only be made after childbirth, by measuring the birth weight.[41] As a result, it is unlikely for the mother to knowingly change her behavior because of fetal macrosomia during pregnancy, therefore precluding an effect of fetal macrosomia on maternal physical activity during pregnancy. In this case a causal interpretation of our finding on fetal macrosomia is arguably less threatened by reverse causality. Admittedly, data on other possible confounding factors, such as those related to compensatory behaviors resulting from strenuous activities at work, remain unobserved. And, collecting more detailed data on maternal activities during pregnancy and potential mechanisms underlying maternal and fetal health (e.g., sleep deprivation and the resulting metabolic changes) would allow for exploring alternative explanations on the association between maternal job strenuousness during pregnancy and maternal and fetal health (e.g., fetal macrosomia) more fully. Regarding the provision of accommodations at work for pregnant women who hold strenuous jobs, as of June 2019, only 27 states and D.C. have passed laws requiring some employers to do so.[42] The effects of strenuous work activities on maternal and fetal health need to factor into any cost-benefit calculus surrounding the policy debate of whether to require employers to provide reasonable accommodations for female workers during pregnancy.

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[41] For details, see https://emedicine.medscape.com/article/262679-overview (accessed in November 2018).

[42] For details, see: http://www.nationalpartnership.org/our-work/resources/workplace/pregnancy-discrimination/reasonable-accommodations-for-pregnant-workers-state-laws.pdf (accessed in August 2019).

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Table 1: Summary Statistics

Samples:	Light-intensity activity at work		Moderate-intensity activity at work		Full sample	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Variables related to physical activity at work						
Moderate-intensity activity at work (1) vs. light-intensity activity at work (0)	0.000	0.000	1.000	0.000	0.113	0.316
Metabolic Equivalent of Task (MET, a continuous measure)	2.027	0.461	3.256	0.441	2.165	0.601
Variables related to pregnancy and birth						
Birth weight (in grams), among singleton births	3,343.435	532.093	3,323.886	542.673	3,341.232	533.322
Fetal macrosomia (1/0): birth weight > 4,000 grams, among singleton births	0.086	0.280	0.083	0.277	0.086	0.280
Low birth weight (1/0): birth weight < 2,500 grams, among singleton births	0.051	0.221	0.056	0.230	0.052	0.222
Gestational length (in weeks), among singleton births	38.763	1.723	38.722	1.754	38.759	1.726
Preterm (1/0): gestational length < 37 weeks, among singleton births	0.070	0.255	0.070	0.255	0.070	0.255
Female baby (1/0)	0.491	0.500	0.512	0.500	0.493	0.500
Variables related to mother						
Mother's body weight prior to pregnancy (in pounds)	153.842	37.749	156.881	39.081	154.184	37.913
Mother's BMI prior to pregnancy	26.245	6.074	26.996	6.223	26.329	6.096
Mother's weight gain during pregnancy (in pounds)	29.836	12.009	28.728	12.821	29.713	12.107
Mother gaining too much weight during pregnancy (1/0)	0.460	0.498	0.459	0.498	0.460	0.498
Gestational diabetes (1/0)	0.067	0.250	0.078	0.268	0.068	0.252
Prepregnancy diabetes (1/0)	0.008	0.087	0.007	0.086	0.008	0.087
Mother's age	31.749	5.005	29.888	5.422	31.539	5.088
Mother being White (1/0)	0.724	0.447	0.557	0.497	0.705	0.456
Mother being Black (1/0)	0.118	0.322	0.280	0.449	0.136	0.343
Mother being Hispanic (1/0)	0.171	0.376	0.287	0.452	0.184	0.387
Mother having completed a four-year college or higher (1/0)	0.609	0.488	0.211	0.408	0.564	0.496
Mother being married (1/0)	0.776	0.417	0.510	0.500	0.746	0.435
Number of previous live births the mother had	0.847	1.093	0.989	1.085	0.863	1.093
Having previous preterm birth (1/0)	0.023	0.150	0.035	0.184	0.024	0.154
Mother had private insurance during pregnancy (1/0)	0.822	0.382	0.558	0.497	0.793	0.405
Mother had Medicaid during pregnancy (1/0)	0.156	0.363	0.381	0.486	0.181	0.385
Mother had prenatal care (1/0)	0.988	0.110	0.987	0.114	0.988	0.110
Mother smoked cigarettes before or during her pregnancy (1/0)	0.067	0.250	0.127	0.333	0.074	0.261
Variables related to mother's residential zip code's characteristics						
Population size (in 10,000) for each zip code	3.021	2.041	3.132	1.786	3.034	2.014
White subpopulation size (in 10,000) for each zip code	2.126	1.651	1.917	1.381	2.102	1.624
Black subopulation size (in 10,000) for each zip code	0.456	0.650	0.712	0.870	0.485	0.683
Hispanic subpopulation size (in 10,000) for each zip code	0.582	0.893	0.810	1.117	0.607	0.923
Number of households (in 10,000) for each zip code	1.071	0.647	1.116	0.596	1.076	0.641
Average number of individuals per household for each zip code	2.722	0.338	2.731	0.324	2.723	0.337
Average house value (in $100,000) for each zip code ($)	3.514	1.270	3.011	1.039	3.457	1.257
Average household income (in $100,000) for each zip code ($)	0.767	0.268	0.641	0.230	0.753	0.267
Median age among all individuals for each zip code	38.621	5.474	37.560	5.413	38.502	5.477
Sample size	27,726		3,521		31,247	

Notes: Data are from the 2014 and 2015 New Jersey birth records on all live births collected by the New Jersey Department of Health. The summary statistics are based on the estimation sample including live and singleton births among mothers who live in New Jersey. In the “light-intensity activity at work” sample, the variables “mother’s weight gain during pregnancy (in pounds)” and “mother gaining too much weight during pregnancy (1/0)” both have 26,763 observations. In the “moderate-intensity activity at work” sample, the variables “mother’s weight gain during pregnancy (in pounds)” and “mother gaining too much weight during pregnancy (1/0)” both have 3,350 observations. In the full sample, the variables “mother’s weight gain during pregnancy (in pounds)” and “mother gaining too much weight during pregnancy (1/0)” both have 30,113 observations. Values of the Metabolic Equivalent of Task (MET) are provided by the Census Occupational Classification System, reflecting the intensity and strenuousness of the work activities performed. Our study compares moderate-intensity activity at work with light-intensity activity at work. That is, the variable named “moderate-intensity activity at work (1/0)” is equal to one if $3 \leq \text{MET} \leq 6$ and equal to zero if $\text{MET} < 3$. The definition of mother gaining too much weight during pregnancy (1/0) is given by the Institute of Medicine Weight Gain Recommendations for Pregnancy (available at https://www.acog.org/Clinical-Guidance-and-Publications/Committee-Opinions/Committee-on-Obstetric-Practice/Weight-Gain-During-Pregnancy, accessed in April 2018), which gives a recommended range of weight gain specific to the mother’s pre-pregnancy body weight category (underweight, normal weight, overweight, and obese). The zip code database is purchased from https://www.zip-codes.com/zip-code-statistics.asp. Zip code level control variables include the population size for each zip code based on the 2010 U.S. Census and the associated White, Black and Hispanic subpopulation sizes for that zip code, the number of households for each zip code based on the 2010 U.S. Census, the average number of individuals per household for each zip code based on the 2010 U.S. Census, the average house value for each zip code based on the American Community Survey five-year estimate, the average household income for each zip code based on the American Community Survey five-year estimate, and the median age among all individuals for each zip code based on the 2010 U.S. Census.

Table 2: Comparisons of Maternal Demographic Characteristics: Moderate-Intensity Activity at Work vs. Light-Intensity Activity at Work

Mother's demographic characteristics:	Coefficient on the dummy variable moderate-intensity activity at work (1/0), which is equal to one for moderate-intensity activity at work and equal to zero for light-intensity activity at work			
	(1)	(2)	(3)	(4)
Mother's age	-1.8568***	-1.1297***	-0.4737***	-0.2170*
	(0.1601)	(0.1184)	(0.1480)	(0.1174)
Mother being White (1/0)	-0.1645***	-0.0857***	-0.0650***	-0.0215**
	(0.0157)	(0.0106)	(0.0121)	(0.0107)
Mother being Black (1/0)	0.1619***	0.0879***	0.0652***	0.0286***
	(0.0143)	(0.0095)	(0.0105)	(0.0078)
Mother being Hispanic (1/0)	0.1135***	0.0529***	-0.0166*	-0.0112
	(0.0173)	(0.0101)	(0.0101)	(0.0091)
Mother having completed a four-year college or higher (1/0)	-0.3973***	-0.2906***	-0.0399***	-0.0122
	(0.0114)	(0.0096)	(0.0125)	(0.0118)
Mother being married (1/0)	-0.2651***	-0.1662***	-0.0725***	-0.0307***
	(0.0104)	(0.0111)	(0.0128)	(0.0106)
Number of previous live births the mother had	0.1405**	0.1275***	0.0414	0.0401*
	(0.0705)	(0.0308)	(0.0308)	(0.0243)
Having previous preterm birth (1/0)	0.0126***	0.0072**	0.0042	0.0029
	(0.0032)	(0.0032)	(0.0046)	(0.0046)
Mother had private insurance during pregnancy (1/0)	-0.2618***	-0.1828***	-0.0598***	-0.0079
	(0.0163)	(0.0103)	(0.0122)	(0.0061)
Mother had Medicaid during pregnancy (1/0)	0.2230***	0.1496***	0.0523***	-0.0010
	(0.0155)	(0.0098)	(0.0118)	(0.0059)
Control variables:				
Individual level demographic variables	No	No	No	Yes
Mother's occupation dummy variables	No	No	Yes	Yes
Mother's residential zip code fixed effects	No	Yes	Yes	Yes
Year and month of birth (i.e., monthly) fixed effects	Yes	Yes	Yes	Yes
Number of observations	31,247	31,247	31,247	31,247

Notes: Data are from the 2014 and 2015 New Jersey birth records on all live births collected by the New Jersey Department of Health. The estimation sample includes live and singleton births among mothers who live in New Jersey. Values of the Metabolic Equivalent of Task (MET) are provided by the Census Occupational Classification System, reflecting the intensity and strenuousness of the work activities performed. Our study compares moderate-intensity activity at work with light-intensity activity at work. That is, the variable named “moderate-intensity activity at work (1/0)” is equal to one if $3 \leq \text{MET} \leq 6$ and equal to zero if $\text{MET} < 3$. Each column is an ordinary least squares (OLS) regression of each of the mother’s demographic characteristics (listed in the table) on that “moderate-intensity activity at work (1/0)” dummy variable and the control variables (listed at the end of the table). Columns (3) and (4) include 22 occupation dummy variables (with one used as the base category and dropped from the regression model). Their definitions are given by Table 3 through Table 24 (i.e., 22 tables) of “MET values for activities in 2002 Census Occupation Classification System (OCS)” (available at https://epi.grants.cancer.gov/physical/MET/#ocs and accessed in April 2018). In column (4), individual level demographic variables controlled for are mother’s BMI prior to pregnancy, infant being female (1/0), mother’s age, mother’s race and ethnicity (1/0 dummy variables for White, Black, and Hispanic), mother having completed a four-year college education or higher (1/0), mother being married (1/0), number of previous live births the mother had, mother having previous preterm birth (1/0), mother having private insurance during pregnancy (1/0), mother having Medicaid during pregnancy (1/0), mother having prenatal care (1/0), and mother having smoked before or during pregnancy (1/0), except the variable used as the dependent variable in the OLS regression. Standard errors (reported in parentheses) are clustered at the zip code level. * p-value < 0.1; ** p-value < 0.05; *** p-value < 0.01.

Table 3: Impacts of Physical Activity at Work during Pregnancy on Birth Outcomes

Outcome variables:	Birth weigth (in grams)		Fetal macrosomia (1/0, equal to 1 if birth weight > 4,000 grams and 0 otherwise)		Low birth weight (1/0, equal to 1 if birth weight < 2,500 grams and 0 otherwise)		Gestational length (in weeks)		Preterm (1/0, equal to 1 if gestational length < 37 weeks and 0 otherwise)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Panel A										
Moderate-intensity activity at work (1) vs. light-intensity activity at work (0)	37.2881***	38.9015***	0.0184**	0.0192**	-0.0001	0.0005	0.0717	0.0647	-0.0110*	-0.0107
	(13.9632)	(14.1900)	(0.0078)	(0.0079)	(0.0058)	(0.0059)	(0.0461)	(0.0466)	(0.0064)	(0.0066)
Mother's BMI prior to pregnancy	9.0248***	9.0410***	0.0043***	0.0043***	-0.0003	-0.0003	-0.0105***	-0.0099***	0.0009***	0.0008***
	(0.5636)	(0.5690)	(0.0003)	(0.0003)	(0.0002)	(0.0002)	(0.0019)	(0.0019)	(0.0003)	(0.0003)
R-squared	0.064	0.081	0.030	0.050	0.016	0.031	0.034	0.053	0.017	0.035
Panel B										
Metabolic Equivalent of Task (MET, a continuous measure)	14.2781	12.4802	0.0095**	0.0094**	0.0019	0.0024	0.0031	0.0017	-0.0009	-0.0006
	(8.7460)	(8.9440)	(0.0046)	(0.0047)	(0.0037)	(0.0038)	(0.0302)	(0.0310)	(0.0043)	(0.0044)
Mother's BMI prior to pregnancy	9.0201***	9.0322***	0.0043***	0.0043***	-0.0003	-0.0003	-0.0105***	-0.0100***	0.0009***	0.0008***
	(0.5640)	(0.5695)	(0.0003)	(0.0003)	(0.0002)	(0.0002)	(0.0019)	(0.0019)	(0.0003)	(0.0003)
R-squared	0.064	0.081	0.030	0.050	0.016	0.031	0.034	0.053	0.017	0.035
Control variables used in Panels A and B										
Individual level demographic variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mother's occupation dummy variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mother's residential county fixed effects	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Mother's residential zip code level control variables	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Mother's residential zip code fixed effects	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Year and month of birth (i.e., monthly) fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	31,247	31,247	31,247	31,247	31,247	31,247	31,247	31,247	31,247	31,247

Notes: Data are from the 2014 and 2015 New Jersey birth records on all live births collected by the New Jersey Department of Health. The estimation sample includes live and singleton births among mothers who live in New Jersey. Values of the Metabolic Equivalent of Task (MET) are provided by the Census Occupational Classification System, reflecting the intensity and strenuousness of the work activities performed. We use different regression models in Panel A and Panel B. In Panel A, we use this dummy variable as a regressor: "moderate-intensity activity at work (1/0)", which is equal to one if $3 \leq \text{MET} \leq 6$ and equal to zero if $\text{MET} < 3$. In Panel B, we use MET (a continuous measure) as a regressor. Individual level demographic variables controlled for are infant being female (1/0), mother's age, mother's race and ethnicity (1/0 dummy variables for White, Black, and Hispanic), mother having completed a four-year college education or higher (1/0), mother being married (1/0), number of previous live births the mother had, mother having previous preterm birth (1/0), mother having private insurance during pregnancy (1/0), mother having Medicaid during pregnancy (1/0), mother having prenatal care (1/0), and mother having smoked before or during pregnancy (1/0). Zip code level control variables include the population size for each zip code based on the 2010 U.S. Census and the associated White, Black and Hispanic subpopulation sizes for that zip code, the number of households for each zip code based on the 2010 U.S. Census, the average number of individuals per household for each zip code based on the 2010 U.S. Census, the average house value for each zip code based on the American Community Survey five-year estimate, the average household income for each zip code based on the American Community Survey five-year estimate, and the median age among all individuals for each zip code based on the 2010 U.S. Census. The estimation sample include 22 occupation dummy variables (with one used as the base category and dropped from the regression model). Their definitions are given by Table 3 through Table 24 (i.e., 22 tables) of "MET values for activities in 2002 Census Occupation Classification System (OCS)" (available at https://epi.grants.cancer.gov/physical/MET/#ocs and accessed in April 2018). Standard errors (reported in parentheses) are clustered at the zip code level. * p -value < 0.1; ** p -value < 0.05; *** p -value < 0.01.

Table 4: Assessing Robustness to Maternal Health Endowment and Risk Factors in the Estimates of Impact of Having Moderate-Intensity Activity at Work during Pregnancy on Fetal Macrosomia

	(1)	(2)	(3)	(4)
Moderate-intensity activity at work (1) vs. light-intensity activity at work (0)	0.0190**	0.0191**	0.0190**	0.0192**
	(0.0079)	(0.0079)	(0.0079)	(0.0079)
Mother's BMI prior to pregnancy	0.0043***	0.0042***	0.0043***	0.0043***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Mother having private insurance during pregnancy (1/0)	No	Yes	Yes	Yes
Mother having Medicaid during pregnancy (1/0)	No	Yes	Yes	Yes
Mother having previous preterm birth (1/0)	Yes	No	Yes	Yes
Mother having prenatal care (1/0)	Yes	Yes	Yes	Yes
Mother smoked cigarettes before or during her pregnancy (1/0)	Yes	Yes	No	Yes
Other control variables				
Individual level demographic variables	Yes	Yes	Yes	Yes
Mother's occupation dummy variables	Yes	Yes	Yes	Yes
Mother's residential zip code fixed effects	Yes	Yes	Yes	Yes
Year and month of birth (i.e., monthly) fixed effects	Yes	Yes	Yes	Yes
R-squared	0.050	0.049	0.050	0.050
Number of observations	31,247	31,247	31,247	31,247

Notes: Data are from the 2014 and 2015 New Jersey birth records on all live births collected by the New Jersey Department of Health. The estimation sample includes live and singleton births among mothers who live in New Jersey. The variable named “fetal macrosomia (1/0)” is equal to one if birth weight > 4,000 grams and equal to zero if birth weight ≤ 4,000 grams. Values of the Metabolic Equivalent of Task (MET) are provided by the Census Occupational Classification System, reflecting the intensity and strenuousness of the work activities performed. Our study compares moderate-intensity activity at work with light-intensity activity at work. That is, the variable named “moderate-intensity activity at work (1/0)” is equal to one if $3 \leq \text{MET} \leq 6$ and equal to zero if $\text{MET} < 3$. Individual level demographic variables controlled for are infant being female (1/0), mother’s age, mother’s race and ethnicity (1/0 dummy variables for White, Black, and Hispanic), mother having completed a four-year college education or higher (1/0), mother being married (1/0), number of previous live births the mother had, and mother having prenatal care (1/0). The estimation sample include 22 occupation dummy variables (with one used as the base category and dropped from the regression model). Their definitions are given by Table 3 through Table 24 (i.e., 22 tables) of “MET values for activities in 2002 Census Occupation Classification System (OCS)” (available at https://epi.grants.cancer.gov/physical/MET/#ocs and accessed in April 2018). Standard errors (reported in parentheses) are clustered at the zip code level. * *p* -value < 0.1; ** *p* -value < 0.05; *** *p* -value < 0.01.

Table 5: Impact of Having Moderate-Intensity Activity at Work during Pregnancy on Fetal Macrosomia, Controlling for Employer Location, Commuting, and Labor Supply Behaviors

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Moderate-intensity activity at work (1) vs. light-intensity activity	0.0159*	0.0160*	0.0153*	0.0152*	0.0137	0.0136	0.0130	0.0129
at work (0)	(0.0083)	(0.0083)	(0.0082)	(0.0082)	(0.0085)	(0.0086)	(0.0084)	(0.0084)
	[0.055]	[0.055]	[0.063]	[0.064]	[0.109]	[0.115]	[0.122]	[0.124]
Mother's BMI prior to pregnancy	0.0042***	0.0042***	0.0042***	0.0042***	0.0042***	0.0042***	0.0042***	0.0042***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Mother's residential zip code fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mother's employer's county fixed effecs	Yes	No	No	No	Yes	No	No	No
Mother's employer's zip code fixed effects	No	Yes	No	No	No	Yes	No	No
Mother's home and employer are in the same county (1/0)	No	No	Yes	No	No	No	Yes	No
Mother's home and employer are in the same zip code (1/0)	No	No	No	Yes	No	No	No	Yes
Other control variables								
Individual level demographic variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mother's occupation dummy variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year and month of birth (i.e., monthly) fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Labor supply measures obtained from the ACS data	No	No	No	No	Yes	Yes	Yes	Yes
R-squared	0.053	0.088	0.051	0.051	0.055	0.090	0.053	0.053
Number of observations	28,503	28,503	28,503	28,503	27,473	27,473	27,473	27,473

Notes: Data are from the 2014 and 2015 New Jersey birth records on all live births collected by the New Jersey Department of Health. The estimation sample includes live and singleton births among mothers who live in New Jersey. The variable named "fetal macrosomia (1/0)" is equal to one if birth weight > 4,000 grams and equal to zero if birth weight ≤ 4,000 grams. Values of the Metabolic Equivalent of Task (MET) are provided by the Census Occupational Classification System, reflecting the intensity and strenuousness of the work activities performed. Our study compares moderate-intensity activity at work with light-intensity activity at work. That is, the variable named "moderate-intensity activity at work (1/0)" is equal to one if 3 ≤ MET ≤ 6 and equal to zero if MET < 3. Individual level demographic variables controlled for are infant being female (1/0), mother's age, mother's race and ethnicity (1/0 dummy variables for White, Black, and Hispanic), mother having completed a four-year college education or higher (1/0), mother being married (1/0), number of previous live births the mother had, mother having previous preterm birth (1/0), mother having private insurance during pregnancy (1/0), mother having Medicaid during pregnancy (1/0), mother having prenatal care (1/0), and mother having smoked before or during pregnancy (1/0). The estimation sample include 22 occupation dummy variables (with one used as the base category and dropped from the regression model). Their definitions are given by Table 3 through Table 24 (i.e., 22 tables) of "MET values for activities in 2002 Census Occupation Classification System (OCS)" (available at https://epi.grants.cancer.gov/physical/MET/#ocs and accessed in April 2018).

In columns (5) through (8) we repeat the estimations conducted in columns (1) through (4), respectively, with the addition of the following six labor supply measures obtained from the 2010–2017 American Community Survey (ACS) data (in which we converted the 2010 Census occupation codes used in the ACS data to the 2002 Census occupation codes used throughout our study): i) usual hours worked in a given week; ii) annual income from wages; iii) commutes to work by car/automobile/motorbike; iv) commutes to work by public transportation or ferryboat; v) commutes to work by bicycle, walking, taxi, or other; and vi) works from home. We limit the ACS data to New Jersey residents, women who gave birth in the previous year or have an own child in the household one year of age or younger, and who worked in the previous year. We merge the ACS data with the New Jersey birth records by each cell defined by having the same occupation code-race (white/black/other)-Hispanic-married-college (or above) educated-age group (16–30 and 31–50). To increase the sample size and statistical power, for observations in the birth data that do not find matches in the ACS data, we use the average values of the aforementioned six measures by each occupation code; these observations are indicated by a dummy variable, which is included in the estimations conducted in columns (5) through (8).

Reported in [brackets] are *p* -values. Standard errors (reported in parentheses) are clustered at the zip code level. * *p* -value < 0.1; ** *p* -value < 0.05; *** *p* -value < 0.01.

Table 6: Impact of Physical Activity at Work during Pregnancy on Fetal Macrosomia, Controlling for Weight Gain and Gestational Diabetes

	(1)	(2)	(3)
Panel A			
Moderate-intensity activity at work (1) vs. light-intensity activity at work (0)	0.0192**	0.0140*	0.0133*
	(0.0079)	(0.0077)	(0.0077)
Mother's BMI prior to pregnancy	0.0043***	0.0056***	0.0037***
	(0.0003)	(0.0003)	(0.0003)
Mother's weight gain during pregnancy (in pounds)		0.0025***	
		(0.0002)	
Mother gaining too much weight during pregnancy (1/0)			0.0503***
			(0.0034)
Gestational diabetes (1/0)		0.0219***	0.0183***
		(0.0068)	(0.0068)
Panel B			
Metabolic Equivalent of Task (MET, a continuous measure)	0.0094**	0.0069	0.0069
	(0.0047)	(0.0047)	(0.0048)
Mother's BMI prior to pregnancy	0.0043***	0.0056***	0.0037***
	(0.0003)	(0.0003)	(0.0003)
Mother's weight gain during pregnancy (in pounds)		0.0025***	
		(0.0002)	
Mother gaining too much weight during pregnancy (1/0)			0.0503***
			(0.0034)
Gestational diabetes (1/0)		0.0221***	0.0184***
		(0.0068)	(0.0068)
Other control variables used in Panels A and B			
Individual level demographic variables	Yes	Yes	Yes
Mother's occupation dummy variables	Yes	Yes	Yes
Mother's residential zip code fixed effects	Yes	Yes	Yes
Year and month of birth (i.e., monthly) fixed effects	Yes	Yes	Yes
Number of observations	31,247	30,113	30,113

Notes: Data are from the 2014 and 2015 New Jersey birth records on all live births collected by the New Jersey Department of Health. The estimation sample includes live and singleton births among mothers who live in New Jersey. In columns (2) and (3), the variables “mother’s weight gain during pregnancy (in pounds)” and “mother gaining too much weight during pregnancy (1/0)” both have 30,113 observations. The variable named “fetal macrosomia (1/0)” is equal to one if birth weight > 4,000 grams and equal to zero if birth weight ≤ 4,000 grams. Values of the Metabolic Equivalent of Task (MET) are provided by the Census Occupational Classification System, reflecting the intensity and strenuousness of the work activities performed. We use different regression models in Panel A and Panel B. In Panel A, we use this dummy variable as a regressor: “moderate-intensity activity at work (1/0)”, which is equal to one if $3 \leq \text{MET} \leq 6$ and equal to zero if $\text{MET} < 3$. In Panel B, we use MET (a continuous measure) as a regressor. The definition of mother gaining too much weight during pregnancy (1/0) is given by the Institute of Medicine Weight Gain Recommendations for Pregnancy (available at https://www.acog.org/Clinical-Guidance-and-Publications/Committee-Opinions/Committee-on-Obstetric-Practice/Weight-Gain-During-Pregnancy, accessed in April 2018), which gives a recommended range of weight gain specific to the mother’s pre-pregnancy body weight category (underweight, normal weight, overweight, and obese). Individual level demographic variables controlled for are infant being female (1/0), mother’s age, mother’s race and ethnicity (1/0 dummy variables for White, Black, and Hispanic), mother having completed a four-year college education or higher (1/0), mother being married (1/0), number of previous live births the mother had, mother having previous preterm birth (1/0), mother having private insurance during pregnancy (1/0), mother having Medicaid during pregnancy (1/0), mother having prenatal care (1/0), and mother having smoked before or during pregnancy (1/0). The estimation sample include 22 occupation dummy variables (with one used as the base category and dropped from the regression model). Their definitions are given by Table 3 through Table 24 (i.e., 22 tables) of “MET values for activities in 2002 Census Occupation Classification System (OCS)” (available at https://epi.grants.cancer.gov/physical/MET/#ocs and accessed in April 2018). Standard errors (reported in parentheses) are clustered at the zip code level. * *p* -value < 0.1; ** *p* -value < 0.05; *** *p* -value < 0.01.

Table 7: Impacts of Physical Activity at Work during Pregnancy on Gestational Diabetes and Weight Gain

Outcome variables:	Mother having gestational diabetes (1/0)		Mother's weight gain during pregnancy (in pounds)		Mother gaining too much weight during pregnancy (1/0)	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A						
Moderate-intensity activity at work (1) vs. light-intensity activity at work (0)	0.0127*	0.0139*	-0.1336	-0.1681	0.0084	0.0069
	(0.0073)	(0.0074)	(0.3084)	(0.3157)	(0.0132)	(0.0135)
Mother's BMI prior to pregnancy	0.0048***	0.0047***	-0.4886***	-0.4901***	0.0139***	0.0137***
	(0.0003)	(0.0003)	(0.0131)	(0.0132)	(0.0007)	(0.0007)
Panel B						
Metabolic Equivalent of Task (MET, a continuous measure)	0.0016	0.0010	0.2736	0.2368	0.0145*	0.0123
	(0.0043)	(0.0044)	(0.1960)	(0.1993)	(0.0085)	(0.0087)
Mother's BMI prior to pregnancy	0.0048***	0.0047***	-0.4883***	-0.4898***	0.0139***	0.0137***
	(0.0003)	(0.0003)	(0.0131)	(0.0132)	(0.0007)	(0.0007)
Other control variables used in Panels A and B						
Individual level demographic variables	Yes	Yes	Yes	Yes	Yes	Yes
Mother's occupation dummy variables	Yes	Yes	Yes	Yes	Yes	Yes
Mother's residential county fixed effects	Yes	No	Yes	No	Yes	No
Mother's residential zip code level control variables	Yes	No	Yes	No	Yes	No
Mother's residential zip code fixed effects	No	Yes	No	Yes	No	Yes
Year and month of birth (i.e., monthly) fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	30,113	30,113	30,113	30,113	30,113	30,113

Notes: Data are from the 2014 and 2015 New Jersey birth records on all live births collected by the New Jersey Department of Health. The estimation sample includes live and singleton births among mothers who live in New Jersey. The definition of mother gaining too much weight during pregnancy (1/0) is given by the Institute of Medicine Weight Gain Recommendations for Pregnancy (available at https://www.acog.org/Clinical-Guidance-and-Publications/Committee-Opinions/Committee-on-Obstetric-Practice/Weight-Gain-During-Pregnancy, accessed in April 2018), which gives a recommended range of weight gain specific to the mother's pre-pregnancy body weight category (underweight, normal weight, overweight, and obese). Values of the Metabolic Equivalent of Task (MET) are provided by the Census Occupational Classification System, reflecting the intensity and strenuousness of the work activities performed. We use different regression models in Panel A and Panel B. In Panel A, we use this dummy variable as a regressor: "moderate-intensity activity at work (1/0)", which is equal to one if $3 \leq \text{MET} \leq 6$ and equal to zero if $\text{MET} < 3$. In Panel B, we use MET (a continuous measure) as a regressor. Individual level demographic variables controlled for are infant being female (1/0), mother's age, mother's race and ethnicity (1/0 dummy variables for White, Black, and Hispanic), mother having completed a four-year college education or higher (1/0), mother being married (1/0), number of previous live births the mother had, mother having previous preterm birth (1/0), mother having private insurance during pregnancy (1/0), mother having Medicaid during pregnancy (1/0), mother having prenatal care (1/0), and mother having smoked before or during pregnancy (1/0). Zip code level control variables include the population size for each zip code based on the 2010 U.S. Census and the associated White, Black and Hispanic subpopulation sizes for that zip code, the number of households for each zip code based on the 2010 U.S. Census, the average number of individuals per household for each zip code based on the 2010 U.S. Census, the average house value for each zip code based on the American Community Survey five-year estimate, the average household income for each zip code based on the American Community Survey five-year estimate, and the median age among all individuals for each zip code based on the 2010 U.S. Census. The estimation sample include 22 occupation dummy variables (with one used as the base category and dropped from the regression model). Their definitions are given by Table 3 through Table 24 (i.e., 22 tables) of "MET values for activities in 2002 Census Occupation Classification System (OCS)" (available at https://epi.grants.cancer.gov/physical/MET/#ocs and accessed in April 2018). Standard errors (reported in parentheses) are clustered at the zip code level. * p-value < 0.1; ** p-value < 0.05; *** p-value < 0.01.

Table 8: Impact of Physical Activity at Work during Pregnancy on Prepregnancy Diabetes, Falsification Check

	(1)	(2)	(3)	(4)
Panel A				
Moderate-intensity activity at work (1) vs. light-intensity activity at work (0)	-0.0013	-0.0012	-0.0013	-0.0012
	(0.0024)	(0.0024)	(0.0024)	(0.0024)
Mother's body weight prior to pregnancy (in pounds)	0.0001***		0.0001***	
	(0.0000)		(0.0000)	
Mother's BMI prior to pregnancy		0.0008***		0.0008***
		(0.0001)		(0.0001)
Panel B				
Metabolic Equivalent of Task (MET, a continuous measure)	-0.0011	-0.0010	-0.0013	-0.0013
	(0.0017)	(0.0017)	(0.0018)	(0.0018)
Mother's body weight prior to pregnancy (in pounds)	0.0001***		0.0001***	
	(0.0000)		(0.0000)	
Mother's BMI prior to pregnancy		0.0008***		0.0008***
		(0.0001)		(0.0001)
Other control variables used in Panels A and B				
Individual level demographic variables	Yes	Yes	Yes	Yes
Mother's occupation dummy variables	Yes	Yes	Yes	Yes
Mother's residential county fixed effects	Yes	Yes	No	No
Mother's residential zip code level control variables	Yes	Yes	No	No
Mother's residential zip code fixed effects	No	No	Yes	Yes
Year and month of birth (i.e., monthly) fixed effects	Yes	Yes	Yes	Yes
R-squared	0.008	0.009	0.025	0.026
Number of observations	31,247	31,247	31,247	31,247

Notes: Data are from the 2014 and 2015 New Jersey birth records on all live births collected by the New Jersey Department of Health. The estimation sample includes live and singleton births among mothers who live in New Jersey. Values of the Metabolic Equivalent of Task (MET) are provided by the Census Occupational Classification System, reflecting the intensity and strenuousness of the work activities performed. We use different regression models in Panel A and Panel B. In Panel A, we use this dummy variable as a regressor: “moderate-intensity activity at work (1/0)”, which is equal to one if $3 \leq \text{MET} \leq 6$ and equal to zero if $\text{MET} < 3$. In Panel B, we use MET (a continuous measure) as a regressor. Individual level demographic variables controlled for are infant being female (1/0), mother’s age, mother’s race and ethnicity (1/0 dummy variables for White, Black, and Hispanic), mother having completed a four-year college education or higher (1/0), mother being married (1/0), number of previous live births the mother had, mother having previous preterm birth (1/0), mother having private insurance during pregnancy (1/0), mother having Medicaid during pregnancy (1/0), mother having prenatal care (1/0), and mother having smoked before or during pregnancy (1/0). Zip code level control variables include the population size for each zip code based on the 2010 U.S. Census and the associated White, Black and Hispanic subpopulation sizes for that zip code, the number of households for each zip code based on the 2010 U.S. Census, the average number of individuals per household for each zip code based on the 2010 U.S. Census, the average house value for each zip code based on the American Community Survey five-year estimate, the average household income for each zip code based on the American Community Survey five-year estimate, and the median age among all individuals for each zip code based on the 2010 U.S. Census. The estimation sample include 22 occupation dummy variables (with one used as the base category and dropped from the regression model). Their definitions are given by Table 3 through Table 24 (i.e., 22 tables) of “MET values for activities in 2002 Census Occupation Classification System (OCS)” (available at https://epi.grants.cancer.gov/physical/MET/#ocs and accessed in April 2018). Standard errors (reported in parentheses) are clustered at the zip code level. * p-value < 0.1; ** p-value < 0.05; *** p-value < 0.01.

Table 9: Heterogeneous Impact of Having Moderate-Intensity Activity at Work during Pregnancy on Fetal Macrosomia

	Infant's sex		Parity		Mother's race		Mother having completed a four-year college or higher		Mother's marital status	
Estimation by subsample:	Male	Female	First born	Not first born	White	Black	Yes	No	Married	Not married
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Moderate-intensity activity at work (1) vs.	0.0237*	0.0163*	0.0196*	0.0220**	0.0191*	0.0299	0.0234*	0.0191*	0.0191*	0.0204*
light-intensity activity at work (0)	(0.0131)	(0.0096)	(0.0107)	(0.0107)	(0.0106)	(0.0186)	(0.0141)	(0.0101)	(0.0104)	(0.0121)
	[0.072]	[0.090]	[0.068]	[0.041]	[0.072]	[0.108]	[0.097]	[0.059]	[0.068]	[0.091]
Mother's BMI prior to pregnancy	0.0050***	0.0035***	0.0033***	0.0050***	0.0050***	0.0024***	0.0047***	0.0039***	0.0046***	0.0036***
	(0.0005)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0006)	(0.0005)	(0.0004)	(0.0004)	(0.0005)
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Other control variables										
Individual level demographic variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mother's occupation dummy variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mother's residential zip code fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year and month of birth fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	15,838	15,409	14,010	17,237	22,021	4,254	17,633	13,614	23,324	7,923

Notes: Data are from the 2014 and 2015 New Jersey birth records on all live births collected by the New Jersey Department of Health. The estimation sample includes live and singleton births among mothers who live in New Jersey. The variable named “fetal macrosomia (1/0)” is equal to one if birth weight $>$ 4,000 grams and equal to zero if birth weight $\leq$ 4,000 grams. Values of the Metabolic Equivalent of Task (MET) are provided by the Census Occupational Classification System, reflecting the intensity and strenuousness of the work activities performed. Our study compares moderate-intensity activity at work with light-intensity activity at work. That is, the variable named “moderate-intensity activity at work (1/0)” is equal to one if $3 \leq \text{MET} \leq 6$ and equal to zero if $\text{MET} < 3$. Individual level demographic variables controlled for are infant being female (1/0) except columns (1) and (2), mother’s age, mother’s race and ethnicity (1/0 dummy variables for White except column 5, Black except column 6, and Hispanic), mother having completed a four-year college education or higher (1/0) except columns (7) and (8), mother being married (1/0) except columns (9) and (10), number of previous live births the mother had except columns (3) and (4), mother having previous preterm birth (1/0) except column (3), mother having private insurance during pregnancy (1/0), mother having Medicaid during pregnancy (1/0), mother having prenatal care (1/0), and mother having smoked before or during pregnancy (1/0). The estimation sample include 22 occupation dummy variables (with one used as the base category and dropped from the regression model). Their definitions are given by Table 3 through Table 24 (i.e., 22 tables) of “MET values for activities in 2002 Census Occupation Classification System (OCS)” (available at https://epi.grants.cancer.gov/physical/MET/#ocs and accessed in April 2018). Standard errors (reported in parentheses) are clustered at the zip code level. Reported in [brackets] are *p* -values. * *p* -value < 0.1; ** *p* -value < 0.05; *** *p* -value < 0.01.

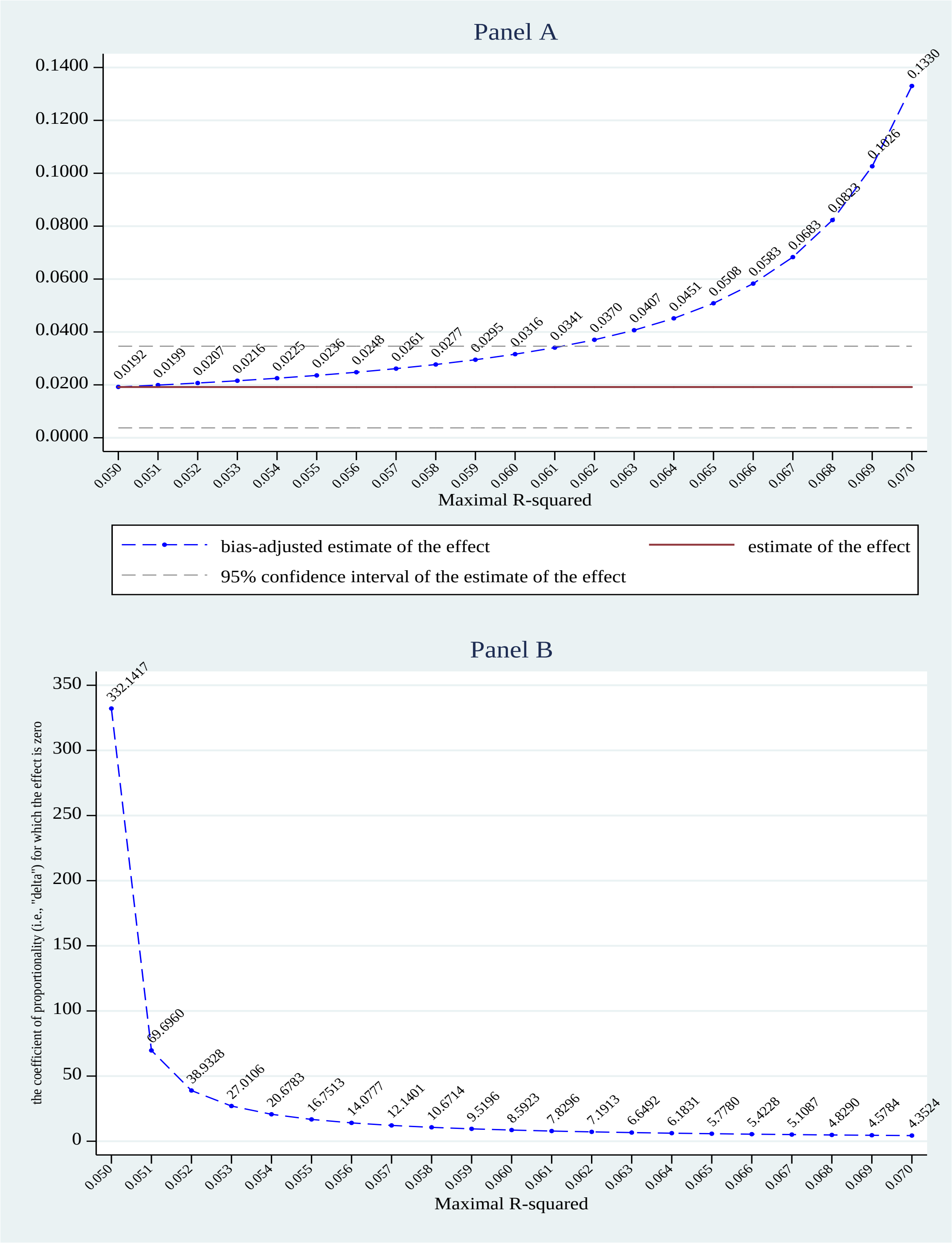

Figure 1: Estimates of the Effect of Having Moderate-Intensity Activity at Work during Pregnancy on Fetal Macrosomia

Notes: In Panel A, the red line represents the estimate of the effect, which is 0.0192, also reported in column (4) and Panel A of Table 3. The bias-adjusted estimate of the effect is referred to as "beta star" in Oster (2019). Also in Oster (2019), the coefficient of proportionality is referred to as "delta," which is the ratio of selection on unobservables divided by selection on observables. In Oster (2019), selection on observables (or unobservables) is characterized by the covariance between the (binary) treatment dummy variable and the observables (or unobservables).