Prenatal Care and Birthweight in Mexico

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Abstract

We estimate the marginal impact of prenatal care on birth outcomes using a nationally representative data on about 14 million births in Mexico. Given the self-selection into prenatal care, we identify the causal impact of prenatal care on birth outcomes by estimating an instrumental variable model. We find positive impacts of increased prenatal visits on birthweight, length, and APGAR score of the newborn. The impacts of prenatal care on birth outcomes differ by mother's education, municipality's development level, and birthweight distribution. We find suggestive evidence that prenatal visit affects birth outcomes through reduction in pre-term births.

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1 Introduction

Low birthweight (LBW) is a major public health challenge in many low-income countries.[1] LBW is considered an important predictor of child survival and key to reducing under-five mortality in less developed countries. Consequently, countries with higher prevalence of LBW also experience high rates of child mortality. For example, among Organization of Economic Co-operation and Development countries Mexico has one of the highest rates of LBW (13.3% in 2009) and under-five mortality rate (1.4%). In addition to its adverse impacts on child survival, LBW may also have negative consequences on adult health, education, and labor market outcomes (Alderman and Berhman 2006; Behrman and Rosenzweig, 2004; Black, Devereux and Salvanes, 2007).

Many governments and international organizations have brought the issue of LBW to the forefront of health policy because of it adverse association with child survival and adult health outcomes. One of the recommended policies to improve infant health is increasing access and utilization of prenatal care (Rosenzweig and Schultz, 1982). However, estimating the impact of prenatal care on birthweight is one of most understudied topics in developing countries. This is an important problem because 96.5% of low birthweight infants are born in these countries. This study contributes to filling this gap by estimating the causal impact of prenatal care (PNC) visits on birth outcomes in Mexico for the period 2008-2014.

Mexico is an ideal country to examine this topic for several reasons. First, among Latin American countries, Mexico has one of the highest incidence of LBW at about 13.3% in 2009 (Buekens et al., 2013). Second, Mexico has implemented Conditional Cash Transfer (CCT) program, *Oportunidades* in 1997, to improve access and utilization of prenatal care. *Oportunidades* led to substantial increase in utilization of PNC in Mexico but the extent of the effect of PNC on birth outcomes is still unknown and unclear. Third, Mexico has

[1] The World Health Organization (WHO) considers newborn infants as LBW and very low birthweight (VLBW) if the birthweight is less than 2,500 grams and 1,500 grams, respectively (regardless of gestational age). The World Bank estimates that more than 20 million infants are born every year as LBW babies.

high-quality data to estimate this relationship, which is unusual for a developing country.

In this study, we use a unique and vast dataset with information on birth outcomes and prenatal visits of about 14 million children from 2008 to 2014 to evaluate the impact of PNC visits on birthweight (BW), incidence of LBW and very low birthweight (VLBW), length of the newborn, and APGAR score.[2] An important challenge when estimating the causal effect of PNC visits on birth outcomes is the possible effect of omitted unobserved variables. In particular, unobserved characteristics of mothers may affect birth outcomes as well as the choice of PNC visits. For example, mothers who are more susceptible to pregnancy risk may decide to seek prenatal care more frequently. Under these circumstances, Ordinary Least Square (OLS) estimations may produce biased results. Therefore, to account for the endogeneity in the choice of prenatal visits and establish causality we use instrumental variable (IV) method. Following Jewell and Triunfo (2006), we use marital status of mother as an instrument for prenatal visits based on the assumption that married women are more likely to seek prenatal care.

We obtain several important results. First, consistent with previous research, we show that OLS estimates underestimate the true effect of prenatal visits on birth outcomes. Second, our IV results indicate that an additional PNC visit increases birthweight by 31 grams and by 1.1 percent. Third, an additional PNC visit also reduces the incidence of LBW by 1.7 percentage points. This represents a 25 percent reduction in LBW at the mean incidence of LBW in our sample. Fourth, while slightly smaller in magnitude, we also find statistically significant effect on VLBW. In addition, we find positive impact of prenatal visits on the length of the infant at birth and the 5-minute APGAR score. Fifth, we find evidence of heterogeneous effects by mother's education level and municipality's development level. In particular, the effect of PNC visits on birthweight is 36% higher in poorer municipalities and 40% higher for less educated mothers. Sixth, our findings are

[2]The APGAR score is a composite index of a child's health at birth and take into account Activity (muscle tone), Pulse (heart rate), Grimace response (reflex irritability), Appearance (skin color), and Respiration (breathing rate and effort). Newborns are usually evaluated at one and five minutes after birth. Each component is worth up to 2 points. The score ranges from zero to ten with higher scores indicating better health.

robust to several robustness checks and sensitivity analyses. Seventh, we also examine the pathway for the impact of PNC visits on birth outcomes and find that improvements in birth outcomes can be explained through increase in the number of gestational weeks. We find that PNC led to higher weeks of gestation and reduced the risk of premature births (births before 36 weeks).

This paper focuses on estimating the causal effect of prenatal visits on birth outcomes in Mexico and contributes to the empirical literature on this topic in the following important ways. First, to the best of our knowledge this is the first study to quantify the effect of prenatal visits on birth outcomes in Mexico in a causal framework. Second, this study is unique with respect to the sample size and representativeness of the sample. This study uses data on approximately 14 million birth observations drawn from over 2400 municipalities, which is one of the most comprehensive available dataset in Mexico on birth outcomes. Third, in contrast to previous empirical studies that mostly focused on birthweight, this paper extends the analysis to other indicators of infant health, such as length of the child and APGAR score. This is important because these health indicators have been found to affect adult outcomes.

The remainder of the paper is organized as follows. Section 2 describes findings of the previous empirical studies on this topic. Section 3 outlines the empirical framework. Section 4 describes the data and presents summary statistics. In Section 5 we present the main results, and in Section 6 we discuss the mechanism. Robustness checks are presented in Section 7 and finally Section 8 concludes and discusses policy implications.

2 Related literature

This paper contributes to the scant and mixed literature on the effect of prenatal care on birth outcomes. Several papers have analyzed this relationship before and present evidence in favor of finding a positive association between prenatal care and birth outcomes. Birthweight is the most frequently analyzed outcome in this literature with infant survival having been been examined in some studies. The literature has differed in the way prenatal care is included in the regression models. While some studies have examined the effect of delay in the initiation of prenatal care on birth outcomes, other studies have explored the effect of the number of prenatal visits on birth outcomes. The size of the effect varies significantly depending on the data, functional forms of the regression model, and context of the country.

Most of the early studies on this topic were conducted in developed countries (Rosenzweig and Schultz, 1983; Joyce 1987; Grossman and Joyce, 1990; Warner 1995, 1998; Conway and Deb, 2005). For example, Rosenzweig and Schultz (1983) reports a decrease in birthweight of 80-91 grams per month delay in seeking prenatal care in the US. Similar to this finding, Grossman and Joyce (1990) also find that delay in prenatal care by one month reduces birthweight in this case by 23-37 grams. Warner (1995) reports a slightly smaller effect of 7 grams decrease in birthweight per week delay in the initiation of prenatal care. Using IV method, Joyce (1994) finds that receiving intermediate prenatal care leads to an increase of over 300 grams in birthweight for babies born to women with higher risks of having adverse birth outcomes.

Using Rosenzweig and Schultz (1983) framework, Warner (1998) finds that the number of prenatal care visits, but not the delays, were significant predictors of birthweight for black and white mothers. In his study, an additional prenatal visit led to an increase in birthweight of 35 and 46 grams for white and black mothers, respectively. Rous, Jewell, and Brown (2004) find a positive impact of prenatal care on birthweight in Texas (USA). Depending on the functional forms, the magnitude of the effects ranged from 15 to 71 grams increase in birthweight per prenatal visit. The detrimental effect of delay in prenatal care was also noted by Evans and Lien (2005). Using a bus strike in Alleghan County in Pennsylvania as an exogenous source of variation in access to prenatal care and as instrument, Evans and Lien (2005) show that loss in prenatal visits due to the bus strike negatively impacted birth outcomes.

Given the low rate of prenatal care and high incidence of LBW in developing countries, econometric exploration of the effect of prenatal care on birth outcomes has gained momentum in recent years. However, econometric studies that clearly account for self-selection in prenatal care and sample selection have been rare for developing countries, including countries in South America. The importance of prenatal care in the production of birthweight was highlighted in previous studies conducted in a limited number of developing countries (Awiti, 2014; Gajate-Garrido, 2013; Jewell and Triunfo, 2006; Jewell, 2007; Wehby et al., 2009; Nazim and Fan, 2011). Using an infant sample from Uruguay and marital status as an instrument, Jewell and Triunfo (2006) reported a decrease of about 57.3 gm on average with each week delay in prenatal care initiation.

Wehby et. al. (2009) reported an increase of about 35 grams per visit and a decrease of 30 grams due to per week delay in initiation of the care in Argentina. They also estimated the effect at different birthweight quantiles and found an increase of 77 grams and 10 grams per visit at the 0.1 and 0.9 quantiles, respectively. In the quantile models, BW decreased by 139 grams at the lowest quantile (0.1) due to per week delay in prenatal care but by only 31 grams at the 0.9 quantiles. Using two-stage least square (2SLS) method, Nazim and Fan (2011) estimate that an additional prenatal visit increases birthweight by about 26g or 0.8% of the mean birthweight in Azerbaijan. They also show that a unit increase in the quality of prenatal care increases birthweight by 21 grams. Using demographic and health survey data from three South American countries of Bolivia, Brazil, and Peru, Jewell (2007) finds that the 2SLS marginal effect of moving to a higher decile of prenatal care is 50.7 grams and delay in initiation of prenatal care by one month reduces the birthweight by 62.5 grams.

Adequate use of prenatal care has also been found to be effective in improving birthweight in the urban areas of Philippines (Gajate-Garrido, 2013) and in Kenya (Awiti, 2014). Using rainfall shock as an instrument for prenatal care, Gajate-Garrido (2013) estimates a very large effect; having adequate number of prenatal care increases birthweight by 666 grams (22% of the average birthweight). The Kenyan study also demonstrates that adequate prenatal care leads to higher birthweight, but the effect was surprisingly large (approximately 2,200 grams).

To sum up, the existing studies provide an overwhelming evidence that prenatal care is an important input in the production of birthweight and a delay in the care or fewer prenatal visits significantly reduce birthweight of the infants. This paper extends and improves on existing research in several important ways. The analysis examines prenatal care in Mexico, a hitherto understudied country with characteristics of both developed and developing countries; it does so with a larger and arguably more representative sample than previous studies; and it extends the outcome variables to other indicators of infant health.

3 Empirical strategy

Our goal is to estimate the causal effect of PNC visits on birth outcomes in Mexico. Previous studies on this topic used an extended version of the infant health production model proposed by Rosenzweig and Schultz (1982, 1983). A common way to model the infant health production function is to estimate the following model with prenatal care as an exogenous variable:

$$Y_{imt} = \alpha_0 + \beta_1 PNC_{imt} + \beta_2 X_{imt} + \beta_3 YOB_t + \gamma_m + \epsilon_{imt} \quad (1)$$

where the unit of analysis is infant i who is born in municipality m in year t. Y_{imt} is the birth outcome variables capturing infant health at the time of birth; PNC_{imt} is the number of prenatal care visits; X is mother and child-level control variables (such as child's gender, birth order, mother's age, mother's education, health insurance); YOB_t is year of birth fixed effects (with t=2008, 2009,....,2014); γ_m is the fixed-effect for municipality; and

ϵ_{imt} is a random error term. In all models, robust standard errors clustered at municipality are used. Our main dependent variable is birthweight, but we also analyze other birth outcomes such as prevalence of LBW and VLBW, weeks of gestation, height of the child at birth, and APGAR score.

β_1 is our main coefficient of interest because it represents the effect of one additional PNC visit on birth outcomes after controlling for mother and child-level variables, and year and municipality fixed effects. However, several factors make the causal interpretation of β_1 in equation (1) problematic. The main concern in equation (1) is the existence of unobserved omitted variables that are correlated with PNC visits and also with birth outcomes. These unobserved omitted variables introduce endogeneity bias in our benchmark model. For example, it is plausible that mothers who are more likely to have complicated pregnancies may decide to consult doctors more frequently, resulting into a biased estimate of β_1.

The standard solution to resolve this endogeneity problem is to use an instrumental variable method. We address this concern by estimating a 2SLS model. As in Jewell and Triunfo (2006) we use the *marital status* of the mother as the instrument for PNC visits. Jewell and Triunfo (2006) argue that marital status of the mother can be good instrument because married mothers are more likely to have planned pregnancies and invest more in their children's health by seeking prenatal care, but the mother's marital status per se may not directly affect birth outcomes. Furthermore, marital status may be a good proxy measure of household's income since married women may have greater access to income and wealth compared to single women. Marital status is used as a dummy variable in our 2SLS model. A potentially better instrument could be the price of PNC visits or household income as exclusion restrictions are more likely to be satisfied but unfortunately this information is not available in our dataset.

The 2SLS model involves estimation of the following two models

$$PNC_{imt} = \alpha_1 + \beta_4 Marital\_Status_{mt} + \beta_5 X_{imt} + \beta_6 YOB_t + \gamma_m + \epsilon_{imt} \quad (2)$$

$$Y_{imt} = \alpha_2 + \beta_7 \widehat{PNC}_{imt} + \beta_8 X_{imt} + \beta_9 YOB_t + \gamma_m + \epsilon_{imt} \quad (3)$$

Equation (2) is the first-stage regression of the endogenous variable on the instrument, while equation (3) is the second stage regression of the outcome variables on the predicted values of the PNC ($\widehat{PNC}$), estimated from equation (1). The basic idea of the 2SLS model is to replace the actual values of PNC (which are correlated with the error term) with $\widehat{PNC}$ that are related to the actual PNC (known as relevance condition) but uncorrelated with the error term (known as exclusion restriction). This way β_7 can capture the unbiased and consistent effect of PNC on birth outcomes. The relevance condition ($Corr(PNC, maritalstatus) \neq 0$) can easily be tested using equation (2). A statistically significant value of β_4 implies that the instrument strongly predicts the endogenous variable. To test the significance of the instrument, the commonly used value of F-statistic is ten (Angrist and Pischke, 2009). A F-statistic greater than ten confirms that the instrument is strongly correlated with the endogeneous variable.

The exclusion restriction requires the instrument (*marital status*) to affect birth outcomes only indirectly through PNC visits. However, we are unable to test the exclusion restriction directly since our model is exactly identified.

An additional concern in our analysis is the possibility of inconsistent estimates as a result of sample selection bias. Sample selection bias can occur when information about the outcome variables (birthweight, height, APGAR score) are missing non-randomly. Vella (1998) argues that the estimation is likely to be affected by sample selection bias when unobserved factors simultaneously affect the dependent variables and the likelihood of inclusion in the sample. For example, several Demographic and Health Surveys (DHS) have reported missing birthweight information for as high as 50% of the children. Sample selection bias is not an issue in our study because information for each of the health outcomes (birthweight, height and APGAR score) is available for 99% of the children and we find no evidence of missing information in a non-random manner.

4 Data

In this study we take advantage of the new birth certificate system implemented by the Health Ministry in Mexico since late 2007: the Subsystem of Information on Births (SINAC). SINAC is part of the National System of Health Information in Mexico (SINAIS 2015). Using the information in SINAC, we assemble a large and unique dataset that includes birth information about the newborn, the mother, and the type of birth of 14 million births in Mexico from 2008 (which is the first full year of national implementation) to 2014.

The initial dataset contains information on 14,388,477 registered live births in Mexico, about two million per year. For this study, we only consider observations for singletons, which reduces our dataset to 14,111,143 observations as multiple births are known to be of lower birthweight. We then drop observations with missing information for the control and outcome variables. To avoid recording errors, we only consider mothers between the ages of 13 and 49, gestational weeks between 26 and 42, and mothers with less than 11 pregnancies. Finally, we drop observations with birthweight less than 500 grams and more than 5000 grams. This implies removing an additional 48,873 observations and yields a sample of 13,347,899 observations (about 93% of the observations in the original dataset). This is our benchmark dataset and contains information for all the control variables.

We analyze the effect of prenatal care visits on several outcomes, which comprehensively capture infant health. Our main outcome variable is birthweight in grams, measured at the time of delivery and log birthweight (there is no evidence of non-normality in the data, the distribution of birthweight is shown in Figure 1). We also analyze the effect of prenatal visit on the probability of LBW and VLBW. LBW is defined as birthweight less than 2,500 grams and VLBW as less than 1,500. LBW (birthweight $< 2{,}500$) is coded as 1 while the reference group of birthweight $> 2{,}500$ is coded as 0. Similarly, VLBW (birthweight $< 1{,}500$) is coded as 1 while the reference group of birthweight $> 1{,}500$ is coded as 0. Height in centimeters and the APGAR score are also analyzed separately as outcome variables.

Table 1 shows the summary statistics of the variables used in our analysis. The average birthweight during our sample period is 3,157, and the percentage of newborns with low and very low birthweight is 6.4% and 0.6%, respectively. The average height of the newborn is 50 centimeters and the mean APGAR score is 8.86 on a maximum scale of 10. The average gestation is 38.85 weeks. However, about 6% of the births are pre-terms as the gestational weeks is less than 36 weeks.

The number of prenatal care visits is our main control variable of interest and the average over the complete sample is 7.23 visits. Only a small percentage of births (2.67%) took place without any prenatal visits and approximately 28% of the births in the sample occurred with less than five prenatal care visits.[3] We also control for several confounding variables that may plausibly affect birth outcomes, such as mother's age, mother's education, marital status, birth order, access to health insurance, gender of the child, and number of pregnancies. The mean maternal age at the time of birth was 25.22 years and about 91% of the mothers completed primary schooling. The mean birth order was 2.23 and 74% of the mothers were covered by health insurance. The average number of pregnancies were 2.23 and 51% of newborns were male indicating absence of sex-selection abortion in Mexico.

[3] The Mexican government recommends at least five prenatal visits, while WHO recommends four prenatal visits before delivery.

5 Results

5.1 Main effects

In Table 2 we report the results from the OLS regression model of equation (1). Columns 1 to 4 present the results on the effect of PNC on birthweight, log of birthweight, and the probability of LBW and VLBW. Column 5 shows the result on length of the child at birth, while column 6 reports the result on the APGAR score. The results in all the six columns control for year of birth and municipality fixed effects. Column 1 shows that PNC visits are positively associated with birthweight. In particular, an additional PNC visit is associated with an increase of 8.8 grams in birthweight. At the average number of 7.2 PNC visits, the OLS coefficient implies an increase of approximately 64 grams. Results in columns 3 and 4 suggest that PNC visits are negatively associated with the probability of LBW and VLBW. We also find that PNC visits are positively associated with length of the child at birth and 5 minutes APGAR score. All the results shown in Table 2 are statistically significant at the conventional level of significance (1%).

However, the OLS results in Table 2 are likely biased estimates and possibly may not be interpreted as the causal effect of PNC visits on birth outcomes because of the endogeneity in the choice of PNC visits: mothers with higher probability of delivering premature and unhealthy babies may decide to have more frequent PNC visits, and may therefore bias the OLS coefficients in Table 2. We cannot distinguish the mothers with the higher risk of delivering LBW babies. However, to establish causality we have to control for this unobserved heterogeneity. As mentioned in Section 3, we address this endogeneity problem by estimating the 2SLS model explained in equations (2) and (3). The results are presented in Table 3.

Table 3 reports the causal effect of PNC visits on birth outcomes. Panel A of Table 3 presents the first-stage results. The first-stage results confirm the instrument's relevance: marital status of women strongly predicts PNC visits. Married women are more likely to visit hospital for prenatal care; married women have 0.71 more PNC visits compared to unmarried women (9.5 percent of the mean PNC visits of 7.2). The Kleibergen-Paap F-stat is 57245.01, indicating that the instrument is strong and statistically significant and our IV model does not suffer from weak-instrument problem. The instrument relevance is robust to the inclusion of control variables, year of birth fixed effects, and municipality fixed effects. Panel B of Table 3 presents the 2SLS results. The 2SLS results are qualitatively similar to the OLS results in that PNC visits are positively correlated with birthweight and other birth outcomes. However, the magnitude of the effects differ substantially.

Since the 2SLS estimates allow us to interpret the results as causal, our preferred results are the estimates from the 2SLS model. We find that an additional PNC visit increases birthweight by almost 31 grams. At the sample mean of birthweight, this implies a 1% increase in birthweight per visit. Comparing the 2SLS to the OLS coefficients we find that the OLS estimates greatly underestimate the true effect of PNC visits on birthweight. The 2SLS effect of 31 grams on birthweight per PNC visit is 3.5 times larger than the OLS effect of 8.8 grams on birthweight. Previous studies that have controlled for endogeneity also report that the OLS results underestimate the true effect of PNC on birthweight.

The average 31 grams increase in birthweight from an additional PNC visit is a relatively large effect with important economic implications. On average, mothers in our sample visit hospitals for prenatal care 7 times during the pregnancy. Thus, at the sample mean, the 2SLS estimate implies an increase of 217 grams (31*7), which amounts to a 6.9% increase at the average birthweight of 3,157 grams. This increase in birthweight is substantial enough to justify investment in policies aimed at improving access and utilization of PNC in Mexico. The results of the log-linear model in column (2) of Panel A in Table 3 also confirm the previous findings. The log-linear model in column (2) shows that an additional PNC visit increases birthweight by 1.1 percent.

We also find that PNC visits have beneficial effects on other birth-related outcomes. An additional PNC visit: i) reduces the probability of LBW and VLBW by 1.2 and 0.2

percentage points, respectively; ii) increases the length of the newborns by an average of 0.09 centimeters, and iii) is associated with an average increase of 0.02 points in the 5-minute APGAR score. The significant coefficient of the APGAR score also implies that the general health condition of the infants born to mothers with different number of PNC differ substantially. To summarize, the results in Table 3 show that, in general, infant health at the time of birth is better if the mother had a higher number of PNC visits.

5.2 Discussion of the results

The results from the previous section show that higher frequency of PNC visits leads to statistically significant increase in birthweight. This has important implications because previous studies have found a negative association between birthweight and neonatal mortality. We are unable to directly explore the effect of PNC visits on neonatal mortality because our dataset does not contain information on neonatal or child mortality. However, we use findings from other studies and do a "back of the envelope" calculation to provide an approximated effect of PNC visits on neonatal mortality. For the USA, Almond, Chay, and Lee (2005)find that a 100 gram increase in birthweight leads to a reduction of 1.5 neonatal deaths per 1,000 live births. Combining this number with our 2SLS findings suggest that the average of 7.2 PNC visits in our sample save about 3.3 neonatal deaths per 1,000 births in Mexico (7.2*31*1.5/100). This is an important number considering that in 2012 Mexico had a neonatal rate of 7.2 deaths per 1,000 live births and about 16,392 neonatal deaths (WHO 2015). This indicates that an additional PNC visit reduces the neonatal death rate by around 0.46 deaths per 1,000 live birth or about 6.4%, which corresponds to 1,047 fewer neonatal deaths per year.

Another way to contextualize the magnitude of our findings is to compare it to other determinants of fetal health and birth outcomes. For example, the Supplemental Nutrition Assistance Program (SNAP) in the USA is a nutritional program that offers nutrition assistance to millions of eligible, low-income individuals and families and provides economic benefits to communities. Similarly, the Supplemental Nutrition Program for Women, Infants, and Children (WIC) is another nutritional supplementation program for low-income pregnant women in the USA. The effect of WIC and SNAP on birthweight range from 2-29 grams and 2-40 grams, respectively (Almond et al., 2011; Hoynes et al., 2011). Thus, our results suggest that PNC visits are more beneficial in improving birthweight than WIC or SNAP.

Finally, as discussed before, Mexico implemented a CCT program *Oportunidades* in 1997 to improve fetal health through nutritional supplementation for pregnant women and improved access to prenatal care. Barber and Gertler (2008) found that newborns exposed to *Oportunidades* in utero weighed 127 grams higher than the unexposed newborns. Our estimated effect on birthweight for one additional PNC visit is economically meaningful compared to the effect of *Oportunidades* (31 grams compared to 127 grams). Our estimates indicate that a quarter of the effect of the *Oportunidades* program can be explained by one prenatal visit. Furthermore, the effect of PNC visits at the mean PNC level of seven visits is 70% higher than the effect of *Oportunidades* program (217 grams vs. 127 grams). We speculate that the difference in the magnitude of the marginal effect of PNC visits and *Oportunidades* on birthweight may be driven by two factors. First, the *Oportunidades* program targeted women from low socioeconomic status, whereas our sample is representative of all income groups. Lack of detailed information in our dataset restricts us from conducting the analysis on a sample similar to the *Oportunidades* sample. Second, *Oportunidades* is a comprehensive program in which prenatal care is just one of the many components.

5.3 Heterogeneous effects

The effects of prenatal care on birthweight may vary by socioeconomic characteristics of the household leading to heterogeneous effects. For example, previous studies have reported that the effectiveness of PNC on birthweight differ by race and mother's education (Grossman and Joyce, 1990; Joyce, 1994; Warner, 1998). Thus, in this subsection we analyze the effect of PNC visits on birth outcomes by observed characteristics of the mother and the mother's municipality of residence.

Ideally, we would want to estimate effects by household or mother's income but our dataset does not contain this information. Instead, we stratify the sample by the municipality's level of development, which is likely to capture economic status of households. We used the development index generated the National Council for the Evaluation of Social Development Policy (CONEVAL 2011). CONEVAL (2011) ranks each municipality by development index, which is a composite index of different measurements of poverty and social development at the municipal level.[4] To simplify our analysis, we categorize the bottom two groups of municipalities as the low development group and the rest as the high development group. About 6% of the municipalities in our dataset are in the low development group.

Panel A in Table 4 shows the results stratified by the municipality's level of development. Results in panel A show that the effect of higher PNC visits on birth outcomes are stronger for children born in municipalities with low development. In particular, the effect of PNC visits on birthweight is 36% higher in municipalities with low development than in high development municipalities. Furthermore, reduction in the probability of infants being born as low birthweight babies is greater by 45% in low development municipalities than the high development municipalities (1.6 vs 1.1 percentage points).

The impact of prenatal care on birth outcomes also differ by mother's education and birthweight of the infants. Results in Panel B of Table 4 indicate that the effect of an additional PNC visit on birthweight is 40% higher for less educated mothers than for mothers who have completed primary schooling. Furthermore, Panel C in Table 4 shows that infants born with less than the median birthweight of 3,150 grams benefit more from PNC visits than infants with a birthweight above the median. For newborns

[4]CONEVAL (2007) provides a detailed explanation on how the development level of each municipality is computed.

with birthweight below the median, the effect of an additional PNC visit is three times larger on birthweight and 70% higher on the APGAR score compared to newborns with birthweight above the median. The effect per PNC visit is higher for newborns of less educated mothers and for newborns with birthweight below the median.

In general, our results in Table 4 show non-uniform effects across the population in the sample as the marginal impact of PNC visits vary by development index of the municipality, mother's education, and birthweight of the newborn. From a health policy perspective, our results underscore the importance of improving access to prenatal care for low-income households and for pregnant women from lower socio-economic status. The return to investment is substantially higher for these population groups.

6 Mechanism linking prenatal visit to birth outcomes

The next step is to test the mechanism that drives the positive effects of prenatal care on birth outcomes. In this section, we examine the possible channels through which PNC visits may affect birth outcomes. Medical and epidemiological studies on birthweight suggest that LBW is mostly caused by premature births (less than 37 weeks of gestation) and intrauterine growth restriction (IUGR). Premature babies are more likely to be LBW because they have less time to grow and most of the gains in weight occurs in the last weeks of the normal pregnancy (Kramer, 2003). In addition, IUGR restricts fetal growth due to placental problems (Villar and Belizán 1982). Ideally, we would want to identify the role of these two mechanisms on LBW, but unfortunately, we are unable to provide empirical evidence on this channel due to the lack of suitable data.

However, our dataset contains information on the gestational age of the newborns and following the medical literature we hypothesize that the effects of prenatal visits on birth outcomes are routed through gestational weeks. To test the weeks of gestation channel, we first divide the weeks of gestation into three categories: 26 to 31 weeks (extreme pre-term births), between 32 to 36 weeks (pre-term births), and 37 to 42 weeks (normal birth length). These three outcomes are dichotomous variables that are equal to one if births are very pre-term, pre-term, and normal and zero otherwise. Second, we run our benchmark specification for each of these three variables. Table 5 shows the 2SLS results of the effect of PNC visits on the weeks of gestation with municipality and year of birth fixed effects. Columns 1 to 3 in Table 5 show that higher frequency of PNC visit decreases the risk of pre-term births and increases the length of gestational weeks. In particular, columns (1) and (2) show that one additional PNC visit reduces the probability of delivery before 32 weeks of gestation and between 32-36 weeks by 0.1 and 0.3 percentage points, respectively. Similarly, an additional PNC visit increases the probability of full-term pregnancies or normal births (37 to 42 weeks) by 0.5 percentage points. These results support the hypothesis that gestational weeks is the pathway through which prenatal care affects birthweight and incidence of LBW in Mexico.

7 Robustness

We also perform several robustness checks to examine the sensitivity of our results. We restrict the sample to mothers who are 20 to 35 years old. We dropped the younger mothers (less than 20 year old) because they are more likely to be risky mothers, have complicated pregnancies, and give births to unhealthy children. Including these younger mothers in the sample may bias our estimate downward. We dropped the older mothers (more than 35 years old) because they may have more exposure to informal education about healthy pregnancies (that are not captured by our education variable) and the importance of prenatal care. Both younger and older women are likely to violate the exclusion restriction as birth outcomes can be affected by other unobserved factors such as riskiness of younger mother and previous pregnancy experience of older women. Older mothers who gave birth before may have additional knowledge on their own risk and preferences and these unobserved factors may affect their choice of prenatal care. At the same time older mothers are also known as high-risk mothers for biological reasons and are more likely to have complicated pregnancies. These factors may bias the results in an unknown way and it is impossible to know direction of the bias ex ante. For these reasons we restrict our analysis to the sample of presumably low-risk mothers. We define mothers in the age group of 20-35 years as low-risk mothers.

Panel A in Table 6 shows the estimates of the baseline model for the low-risk mothers who are 20 to 35 years old. This new sample does not qualitatively affect the results when we compare the new results in Table 6 with those in Table 3. Results show that when we exclude the teenage and older mothers, we continue to find significant effects of PNC visits on birth outcomes. To ward off the concern that prior pregnancies may affect the choice of prenatal care, we further restrict our sample to low-risk mothers with only one birth. This reduces the sample to 2,163,932 births. Once again, our main findings remain unchanged. Furthermore, we also re-estimated the baseline model with an additional covariate "number of prior pregnancies" on the unrestricted sample, but the substantive findings are unchanged in this case too (results available upon request). Taken together, the results are robust even in the sample of low-risk mothers and we find no evidence that our main findings in Table 3 are influenced by high-risk mothers.

There may be a concern that municipalities with fewer births may be different than municipalities with more births. The mean number of births per municipality is 54,964 in the sample. To ensure that municipalities with fewer births are not generating spurious results or biasing our main findings, we conducted additional analyses by dropping municipalities with fewer births. Panel B in Table 6 shows the results for different sample sizes. The results when we remove municipalities with fewer than 100, 500 and 1,000 observations are similar to those for the whole sample in Table 3.[5] Finally, when we ran our baseline model on 5% sample, results are statistically indistinguishable compared to

[5] Removing these municipalities reduces the analysis sample by 1.25%.

results in Table 3, confirming again that the positive effect of prenatal care on birth outcomes is not driven by large sample sizes. To summarize, the baseline results presented in Table 3 (which are our main findings) are robust to a variety of sensitivity checks as shown in Table 6. Together, these results highlight the gain in birth outcomes from prenatal care in Mexico.

8 Conclusion

Poor infant health such as low birthweight, stunted size, and lower APGAR score pose a significant challenge to policy makers in developing countries as they impose significant financial burden on households, healthcare system, education, and social services. Therefore, improving birth outcomes and infant health are crucial public health goals for policy makers in developing countries. Prenatal care is an important determinant of birth outcomes. The true effect of prenatal care as an input in the production of birth outcomes is however not well understood. To our knowledge, no causal analysis has previously been conducted on the impact of prenatal care on birth outcomes in Mexico. This study is the first to examine the impact of prenatal care visits on birth outcomes in Mexico for the period 2008-2014. To overcome the potentially endogenous relationship between prenatal care and birth outcomes, we implement an instrumental variable method that exploits the variation in marital status of the mother as an instrument for prenatal visit. We analyze 14 million live births in Mexico and find significantly positive impacts of prenatal visits on several indicators of infant health. Further, we establish that the effect of prenatal visits on birthweight, height, and APGAR score is mediated through gestational weeks. Higher frequencies of prenatal visits have significant positive impacts on the number of gestational weeks. Our main findings survive several robustness checks.

Although our study offers several advantages such as the large sample size and quality of data, it also has a few limitations. First, we only look at infant health at birth but we do not examine any later-life outcomes such as education or mid-childhood health or maternal health during childbirth. Second, we do not account for the quality of prenatal care due to the lack of data on this variable. Third, there can be measurement errors in the birthweight, height, and APGAR score data. This could bias our main results in unknown ways. Fourth, our estimated effects may be biased due to selective mortality or adverse selection in the data. That is, only surviving infants who are more likely to be healthier are observed in the data and this may change the composition of the surviving pool of infants in the dataset. If healthier infants are positively selected then our main 2SLS results provide the lower bound and underestimate the effect of prenatal care on birth outcomes. In case of negative selection, the estimated effect will be upward biased. Fifth, lack of information on maternal health behavior is another limitation as mother's behavior with regard to smoking, alcohol, and nutritional habits during pregnancy have been causally linked to low birthweight. Finally, data limitation restricts us from including maternal anthropometric characteristics, such as maternal height and pregnancy weight. Previous studies have found positive correlation between maternal anthropometric and fetal growth (Warner, 1998). Future research should attempt to address these concerns.

Nevertheless, the findings of this study suggest that promoting prenatal care can be an effective policy to improve birth outcomes and infant health and to reduce the incidence of low birthweight in developing countries. The sub-group analyses further establish the importance of formulating prenatal care policies targeted towards low-income and less educated women. Introduction of policies similar to WIC in the US for pregnant women at higher risk for having infants with lower birthweight could potentially improve birth outcomes. Providing additional resources to the poor municipalities could also help reduce the incidence of adverse birth outcomes in Mexico.

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Table 1: Descriptive Statistics

Variable	Mean/%	SD	Min.	Max.	N
Outcome variables					
Birthweight (BW) (grams)	3156.65	476.77	500	5000	12,988,237
Low birthweight (LBW) (%)	0.064	0.244	0	1	12,988,237
Very low birthweight (VLBW) (%)	0.006	0.076	0	1	12,988,237
Height (centimeters)	50.07	2.67	30	60	13,121,779
APGAR	8.86	0.86	0	10	13,200,702
Weeks of gestation	38.85	1.63	26	42	13,347,899
Weeks of gestation (26-31)	0.6%				
Weeks of gestation (32-36)	5.3%				
Weeks of gestation (more than 37)	94.09%				
Control variables					
Number of prenatal care visits	7.23	3.28	0	30	13,347,899
Prenatal visits (categorical)					
0 visits	2.67%				
1-5 visits	24.88%				
6-10 visits	63.01%				
More than 10 visits	9.44%				
Mother's age	25.22	6.25	13	49	13,347,899
Maternal education (Primary complete)	0.91	0.28	0	1	13,347,899
Birth order	2.23	1.36	1	10	13,347,899
Health Insurance	0.75	0.44	0	1	13,047,705
Male child	0.51	0.50	0	1	13,347,899
Number of pregnancies	2.23	1.36	1	10	13,347,899
Instrument					
Single mother(%)	0.10	0.30	0	1	13,347,899
Number of municipalities	2456				

Table 2: OLS results of Prenatal Care on Birth Outcomes

	Birthweight Variables					
	BW	Log BW	LBW	VLBW	Height	APGAR
	(1)	(2)	(3)	(4)	(5)	(6)
Prenatal visits	8.835***	0.003***	-0.004***	-0.001***	0.034***	0.008***
	(0.284)	(0.000)	(0.000)	(0.000)	(0.002)	(0.001)
Year of birth f.e.	Yes	Yes	Yes	Yes	Yes	Yes
Municipality f.e.	Yes	Yes	Yes	Yes	Yes	Yes
Mean of dependent variable	3157.1	8.04	0.064	0.006	50.1	8.87
Observations	12,699,280	12,699,280	12,699,280	12,699,280	12,829,079	12,908,047

Notes: Robust standard errors clustered at the municipality level are shown in parentheses. Each column lists estimates from separate regressions. Control variables: Birth order, gender of the child, mother's education, covered under health insurance, Mother's age and age square. * significant at 10%; ** significant at 5%; *** significant at 1%.

Table 3: 2SLS Results of Prenatal Care on Birth Outcomes

	Birthweight Variables					
	BW	Log BW	LBW	VLBW	Height	APGAR
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: First stage, Dependent variable: Number of prenatal visits						
Women is married	0. 707***	0. 707***	0. 707***	0. 707***	0.711***	0.711***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Kleibergen-Paap F-statistic	57245.01	57245.01	57245.01	57245.01	58322.36	58678.03
Panel B: 2SLS results						
Prenatal visits	30.68***	0.011***	-0.012***	-0.002***	0.090***	0.017***
	(0.635)	(0.0002)	(0.0003)	(0.0001)	(0.004)	(0.001)
Year of birth f.e.	Yes	Yes	Yes	Yes	Yes	Yes
Municipality f.e.	Yes	Yes	Yes	Yes	Yes	Yes
Mean of dependent variable	3157.1	8.04	0.064	0.006	50.1	8.87
Observations	12633625	12633625	12633625	12633625	12762815	12841042

Notes: Robust standard errors clustered at the municipality level are shown in parentheses. Each column in each panel lists estimates from separate regressions. Control variables: Birth order, gender of the child, mother's education, covered under health insurance, Mother's age and age square. *significant at 10%; ** significant at 5%; *** significant at 1%.

Table 4: Heterogeneous effects of Prenatal Care on Birth Outcomes (2SLS results)

	Birthweight Variables					
	BW	Log BW	LBW	VLBW	Height	APGAR
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Municipality development group						
High	30.440***	0.011***	-0.011***	-0.002***	0.088***	0.017***
	(0.657)	(0.0002)	(0.0003)	(0.0001)	(0.004)	(0.001)
Low	41.215***	0.015***	-0.016***	-0.002***	0.154***	0.015*
	(2.444)	(0.001)	(0.001)	(0.000)	(0.013)	(0.007)
Panel B: Mother's education						
Completed primary	29.523***	0.011***	-0.011***	-0.002***	0.095***	0.017***
	(0.681)	(0.0002)	(0.0004)	(0.0001)	(0.004)	(0.001)
Less than primary	42.856***	0.015***	-0.015***	-0.001***	0.102***	0.017***
	(1.639)	(0.001)	(0.001)	(0.000)	(0.009)	(0.004)
Panel C: Birth weight						
Above median BW	5.558***	0.002***	-	-	-0.001	0.012***
(3,150 grams)	(0.604)	(0.000)	-	-	(0.005)	(0.002)
Below median BW	18.750***	0.008***	-0.014***	-0.003***	0.076***	0.021***
(3,150 grams)	(0.584)	(0.000)	(0.001)	(0.000)	(0.005)	(0.002)
Year of birth f.e.	Yes	Yes	Yes	Yes	Yes	Yes
Municipality f.e.	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Robust standard errors clustered at the municipality level are shown in parentheses. Each cell lists estimates from separate IV regressions. *Control variables*: Birth order and gender of the child, mother's education, access to health insurance, mother's age and age square. *significant at 10%; ** significant at 5%; *** significant at 1%.

Table 5: Mechanism: 2SLS estimates of Prenatal Care on Weeks of Gestation

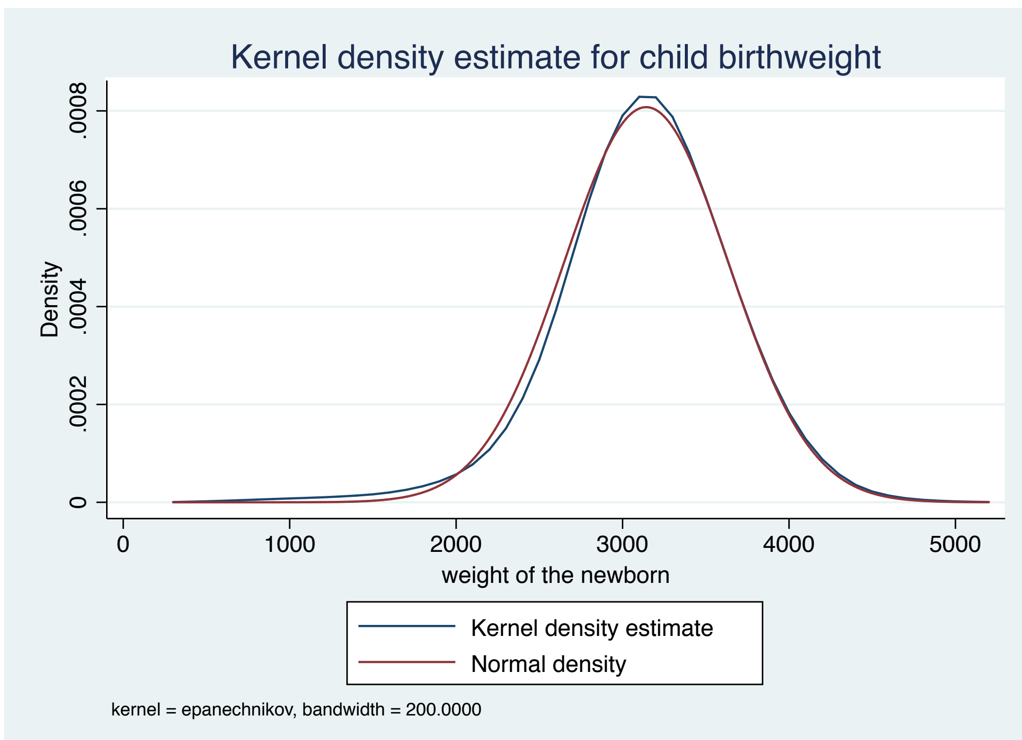
	Weeks of Gestation		
	26-31	32-36	37-42
	(1)	(2)	(3)
Prenatal visits	-0.001***	-0.003***	0.005***
	(0.0001)	(0.0005)	(0.0005)
Year of birth f.e.	Yes	Yes	Yes
Municipality f.e.	Yes	Yes	Yes
Observations	12633625	12633625	12633625

Notes: Robust standard errors clustered at the municipality level are shown in parentheses. Each column in each panel lists estimates from separate regressions. Control variables: Birth order, gender of the child, mother's education, covered under health insurance, Mother's age and age square. *significant at 10%; ** significant at 5%; *** significant at 1%.

Table 6: Robustness checks: 2SLS estimates of Prenatal Care on Birth Outcomes

	Birthweight Variables					
	BW	Log BW	LBW	VLBW	Height	APGAR
	(1)	(2)	(3)	(4)	(5)	
Panel A: Low-risk mothers						
Mother's age	36.50***	0.013***	-0.014***	-0.003***	0.108***	0.022***
(20-35 years)	(0.781)	(0.0003)	(0.0004)	(0.0001)	(0.005)	(0.001)
Single pregnancy mother's	34.67***	0.013***	-0.012***	-0.002***	0.093***	0.023***
(age 20-35 years)	(1.65)	(0.0005)	(0.0008)	(0.0002)	(0.017)	(0.003)
Panel B: Alternative samples						
Municipalities	30.669***	0.011***	-0.011***	-0.002***	0.090***	0.017***
with >100 obs	(0.635)	(0.0002)	(0.0003)	(0.0001)	(0.004)	(0.001)
Municipalities	30.654***	0.011***	-0.011***	-0.002***	0.090***	0.017***
with > 500 obs	(1.091)	(0.0004)	(0.0005)	(0.0001)	(0.009)	(0.002)
Municipalities	30.591***	0.011***	-0.011***	-0.002***	0.089***	0.017***
with >1000 obs	(1.104)	(0.0004)	(0.0005)	(0.0001)	(0.009)	(0.002)
5% sample	30.832***	0.011***	-0.012***	-0.002***	0.100***	0.020***
(N: 631393)	(2.971)	(0.001)	(0.002)	(0.001)	(0.018)	(0.005)
Year of birth f.e.	Yes	Yes	Yes	Yes	Yes	Yes
Municipality f.e.	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Robust standard errors clustered at the municipality level are shown in parentheses. Each column in each panel lists estimates from separate regressions. Control variables: Birth order, gender of the child, mother's education, covered under health insurance, Mother's age and age square. *significant at 10%; ** significant at 5%; *** significant at 1%.


Kernel density estimate for child birthweight
Density
0
.0002
.0004
.0006
.0008
0
1000
2000
3000
4000
5000
weight of the newborn
Kernel density estimate
Normal density
kernel = epanechnikov, bandwidth = 200.0000