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The Quantile effects of prenatal care on birth weight in Mexico

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Abstract

Prenatal care has long been identified as an effective strategy to reduce the risk of low birth weight among infants; however, most studies ignore endogeneity and distributional effect of prenatal care on birth weight. Using instrumental variable quantile regression method, we estimate the effect of prenatal care on birth weight at different quantiles of the birth weight distribution. We find that the effect of a prenatal visit on birth weight is heterogeneous across birth weight quantiles. Infants at the lower birthweight quantiles benefit more from prenatal care compared with infants at the higher birthweight quantiles. The marginal effect of prenatal care visit is 52 grams at the 10th quantiles versus 34 grams at the 90th quantiles. Targeted policies aimed at improving access to prenatal care for women at higher risk of giving birth to low birth infants may help improve the birth endowment of infants.

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1. Introduction

Poor neonatal outcomes including birth weight have been found to have adverse long-term consequences for cognitive and non-cognitive development of children. Low birth weight infants, defined as birth weight less than 2,500 grams, are more likely to have fewer years of schooling, lower IQ, higher rates of unemployment, and earn lower wages (Behrman and Rosenzweig 2004; Currie and Vogl 2013, Kumar *et al*. 2019). Prenatal care (PNC) is widely perceived to be an effective health service to improve neonatal outcomes, particularly birth weight, through its direct impacts on the risk of low birth weight, pre-term births, and other pregnancy-related conditions. PNC is defined as the medical care received from health professionals during pregnancy.

Although a positive association exists between prenatal care utilization and birth weight (Gonzalez and Kumar 2018), whether prenatal care affects birth weight differently over the distribution of birth weight is much less thoroughly examined and continues to remain an important economic inquiry. In the presence of non-uniform effects, the average treatment effects mask heterogeneity in the PNC effects at different birth weight quantiles. Previous studies have found that prenatal care is more effective and larger in magnitude at lower quantiles compared with higher quantiles of birth weight distribution (Abrevaya 2001; Wehby *et al*. 2009).

Another issue in the literature is establishing causality in the distributional effects of PNC on birth weight. Estimating the causal effects of PNC on birth weight is challenging due to the endogeneity of prenatal care. Self-selection into prenatal care, which is likely to be correlated with unobserved behavior or health status of pregnant women, would bias the true causal effects of PNC on birth weight. For example, if pregnant women demand more prenatal care because of better (poorer) health conditions, the effects of prenatal care would be overestimated (underestimated). In this paper, we estimate the causal effects of prenatal care on birth weight in Mexico using an instrumental variable quantile regression (IVQR) methodology that addresses heterogeneity and endogeneity simultaneously. A better understanding of how prenatal care affects birth outcomes of infants would help design public health policies. To the best of our knowledge, this is the first study to examine the distributional effects of prenatal care at birth weight quantiles in Mexico and also account for the endogenous choice of prenatal care use. Mexico is a unique setting to examine this relationship as it has one of the highest prevalence of low birth weight infants among the group of Latin American countries (13%). Additionally, Mexico has also pioneered the successful implementation of a conditional cash transfer scheme, Oportunidades or PROGRESA, to improve access to prenatal services and birth outcomes. Our study contributes to the existing evidence on the effectiveness of prenatal care in reducing the burden of low birth weight in developing countries. Our estimation technique further allows us to explore the effects of prenatal care on birthweight over the entire distribution of birthweight.

2. A brief overview of the existing literature

There have been a few studies that estimated the effects of increased use of prenatal care on birth weight, most of which found a positive association between prenatal use and birth weight of children. Using Demographic and Health Survey data from South American countries of Bolivia, Brazil, Columbia, and Peru, Jewell (2007) found a positive effect of increased prenatal care use on birthweight. The marginal effect of moving to a higher decile of prenatal care use (from an average of 6 to 7 visits) was 51 grams in this study. 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. Using a two-stage least square (2SLS) method, Habibov and Fan (2011) estimate that an additional prenatal visit increases birth weight by about 26g or 0.8% of the mean birth weight in Azerbaijan. They also show that a unit increase in the quality of prenatal care increases birth weight by 21 grams.[1]

Our study, in spirit, is similar to the study conducted by Wehby *et al.* (2009) in Argentina. They address endogeneity by estimating 2SLS and IVQR models; the instruments were area-level characteristics (at the province level) that represent the overall availability of and accessibility to health care and included population per hospital bed, unemployment rate and rate of uninsured females. The OLS and 2SLS models showed a marginal effect of 24 and 35 grams per visit, respectively. In the quantile regression (QR) models, they found a higher impact of the prenatal visit on birthweight at the lower tail of birthweight distribution compared with the estimates at the higher tail of the birthweight distribution. Birthweight increased by 29 grams at the 10^{th} quantiles versus 11 grams at the 90^{th} quantiles. Furthermore, as expected, the IVQR results were larger than the QR estimates: an additional prenatal visit increased birth weight by 77 grams at the 10^{th} quantiles but only by 10 grams at the 90^{th} quantiles. In summary, the existing studies provide credible empirical evidence that prenatal care is an important input in the production of birth weight, and a delay in the care or fewer prenatal visits may worsen the prevalence of low birth weight in resource-poor countries.

3. Methods and Data

3.1 Data description

We use hospital-based birth record data from the Subsystem of Information on Births (SINAC). The SINAC dataset contains birth information for 14 million neonates born between 2008-14. For computational ease, we analyze randomly drawn 1% of the SINAC sample and restrict the sample to 13-49 years old mothers, and singleton births with birth weight ranging 500-5000 grams, and mothers who had fewer than 11 pregnancies (see Kumar and Gonzalez 2018 for data details). The outcome variable, birth weight, has an average value of 3,204 grams, and the main explanatory variable, prenatal care (PNC) is a continuous variable and is measured by the frequency of prenatal visits during pregnancy. It ranges from 0 to 30 visits in our sample. The mean and median PNC visit is 7.3 and 7, respectively. On average, mothers are young (25 years), married (90%), and have completed primary schooling (91%) (Table I). We group legally married couples and those in consensual unions in the married category. Three-fourths of the sample was covered by health insurance and the mean birth order was 2.2. The majority of the infants were born full terms (74%).

[1] Azerbaijan is a low-income transitional country located in the South Caucasus between Russia, Iran and Turkey.

Table I. Descriptive statistics of the sample (N = 129,850)

	Mean	SD	Min	Max
Birth weight (grams)	3204.02	421.01	500	5000
Prenatal visits	7.26	3.25	0	30
Mother's characteristics				
Marital status of the mother	0.90	0.30	0	1
Mother's age (years)	25.17	6.21	13	49
Mother's education (completed primary school)	0.91	0.28	0	1
Child characteristics				
Birth order of the infant	2.22	1.35	1	10
Gender of the infant (male)	0.51	0.49	0	1
Health insurance coverage	0.74	0.44	0	1
Gestational weeks	39.12	1.10	37	42
Number of states	32			

Notes: SD- Standard deviations. Mother's education refers primary school completion.

3.2 Empirical strategy

We use a quantile regression (QR) and an instrumental variable quantile regression (IVQR) to estimate the distributional effects of the use of prenatal care on the birth weight of the newborns. While the ordinary least square (OLS) regression model estimates the mean effects, the QR model is the appropriate regression model to describe the heterogeneous effects of prenatal use on the entire conditional distribution of birth weight. Quantile regression can, therefore, help us obtain a more complete picture of the PNC effects at different levels of the birth weight distribution. Quantile regression is also robust and less sensitive to the presence of outliers in the dependent variable. The conditional quantile function of y_i given x_i can be expressed as

$$Q\tau\ (y_i|x_i) = x_i\beta\tau \tag{1}$$

with $Q\tau\ (y_i|x_i)$ being the conditional quantile function at quantile τ, with $0 < \tau < 1$, and $\beta\tau$ represents the vector of parameters to be estimated. Parameters are obtained by minimizing:

$$\min_{\beta\tau} \frac{1}{N} \left\{ \sum_{i:y_i \geq x_i\beta\_\tau} \tau|y_i - x_i\beta\tau\ | + \sum_{i:y_i < x_i\beta\tau} (1-\tau)|y_i - x_i\beta\tau| \right\} \tag{2}$$

We simultaneously estimate the quantile functions at nine different levels of the conditional distribution of the birth weight (τ = 0.10, 0.20, 0.30. 0.40, 0.50, 0.60, 0.70, 0.80, 0.90). Because the association between PNC and birth weight is likely to be affected by other factors, we employ a multivariate approach to minimize omitted variable bias. These control variables include the mother's age, the square of the mother's age, mother's education, birth order, the gender of the infant, and whether the mother had insurance coverage during pregnancy. In addition to these variables, we also include state and year of birth fixed effects. State fixed-effects capture the time-invariant state-specific variation in birth weight and year of birth fixed effects adjust for common time trends across states. As robustness checks, we also estimate interquantile range regressions to analyze the statistical significance in the difference in coefficients of the quantile regressions. The standard errors are obtained via bootstrapping and use 100 replications.

As mothers self-select into prenatal visits, there may be unobserved factors (mother's health behavior or status) that could simultaneously affect the demand for prenatal visits and production function of birth weight. Such unobserved heterogeneity could potentially result in biased effects of PNC on birth weight. For example, mothers with healthier behavior or with pregnancy complications (poorer health status) may demand more PNC mothers. With everything else constant, the PNC effects on birth weight would be overestimated if mothers practiced healthy behavior and underestimated if mothers have poor health status. Therefore, to obtain unbiased and consistent estimates of the distributional effects of PNC on birth weight, we control for the endogeneity by estimating an IVQR model. The estimates from the IVQR model are our preferred results.

In the IVQR model, the endogenous variable prenatal care is instrumented by the marital status of the mother. The instrument should satisfy two conditions: (i) relevance condition (*Corr (PNC, marital status)* $\neq 0$) and (ii) the exclusion restriction that the instrument should not have a direct effect on the outcome variable. Previous research has instrumented PNC by marital status of the mothers and has shown that marital status is strongly correlated with prenatal visits (Jewell and Triunfo 2006; Gonzalez and Kumar 2018). Both studies argue that married mothers generally have planned pregnancies and therefore, have a higher demand for PNC. Our results find that the instrument satisfies the relevant condition as it significantly predicts higher demand for prenatal use (Table II). The F-stat (305.7) is substantially greater than the accepted threshold of 10.

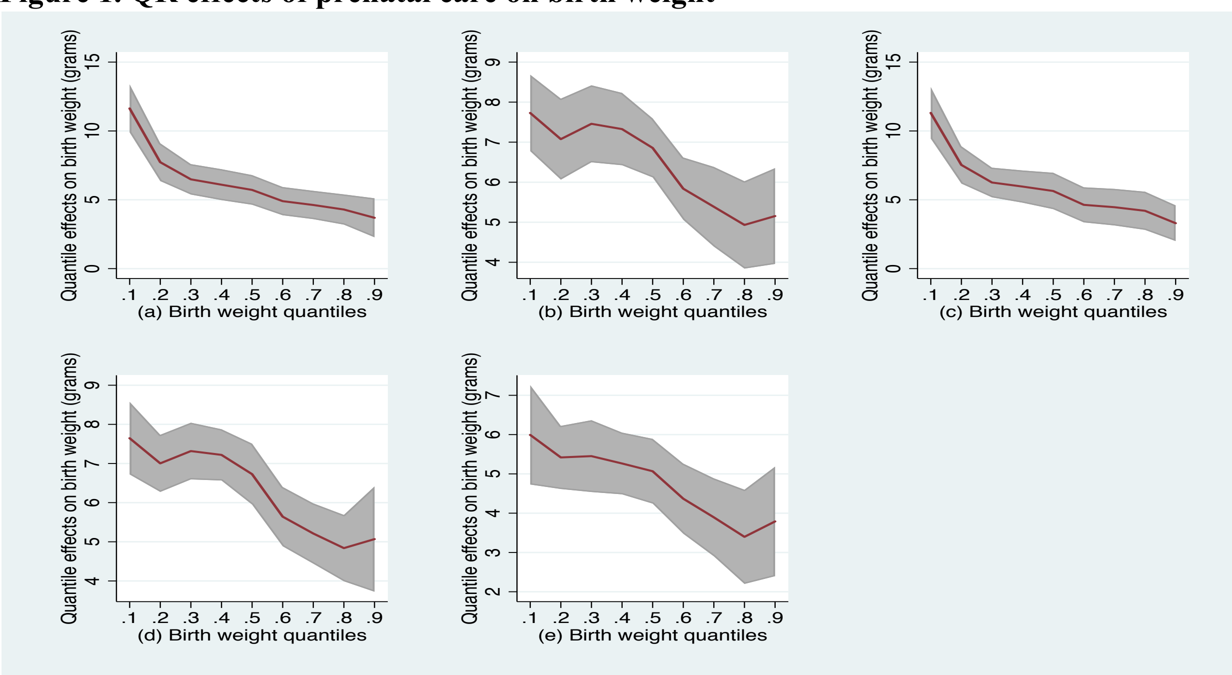
The second condition of the instrument's exogeneity is difficult to test statistically. If marital status affects birth weight through channels other than PNC, for example, through better nutrition, higher household income, greater emotional support, or reduced stress, then exclusions restriction would be violated. Nevertheless, we believe that controlling for mother's education and age should be able to address these concerns somewhat because older and educated women are more likely to work and earn a higher income. The evidence on marriage premium on birth weight is weak in a middle-income country (Kim and Lee 2017). Kim and Lee (2017) found an insignificant effect of marital status on birth weight in Korea. However, we note that if there exists a positive effect of marriage on birth weight, our estimated IVQR or 2SLS effects would be overestimated.

We estimate the IVQR model in two steps: (i) using ordinary least square (OLS) method, the PNC variable is regressed on the instrument and other exogenous variables and (ii) birth weight is regressed on the predicted value PNC from (i) and other exogenous variables in a QR model. We use bootstrap with 100 replications to estimate reliable standard errors because the second stage regression does not take into account that PNC is estimated from the first stage. For comparison, we also report OLS and two-stage least square (2SLS) estimates using the same specification as in QR and IVQR regressions.

4. Results

The OLS results in Table II show that an extra prenatal care visit increases birth weight by 8 grams, after adjusting for mother's age, mother's education, birth order, and gender of the child. The birthweight effect is statistically significant at the 1% level of significance. However, a more nuanced picture of the effects of prenatal care on birthweight emerges when we examine the PNC effect across different quantiles of the birthweight distribution. Figures 1 and 2 present the estimation results for the QR and IVQR model described in the method section, respectively. The y-axis represents changes in birth weight measured in grams and the x-axis represents the respective birth weight quantile. Panel A in Figures 1-2 shows the results from the main specification. However, to test the validity of our main findings, we also show the results from a series of augmented models in Panels B-E. These include a control for *gestational weeks* (Panel B), a control for *access to health insurance* (Panel C), simultaneous control for *gestational weeks and insurance access* (Panel D), and in panel E, model adjusted for gestational weeks and health insurance are estimated only for *full-term births (37-42 weeks)*. The previous study has shown that gestational week and health insurance are a significant determinant of birth weight in Mexico (Kumar and Gonzalez 2018).

Figure 1. QR effects of prenatal care on birth weight

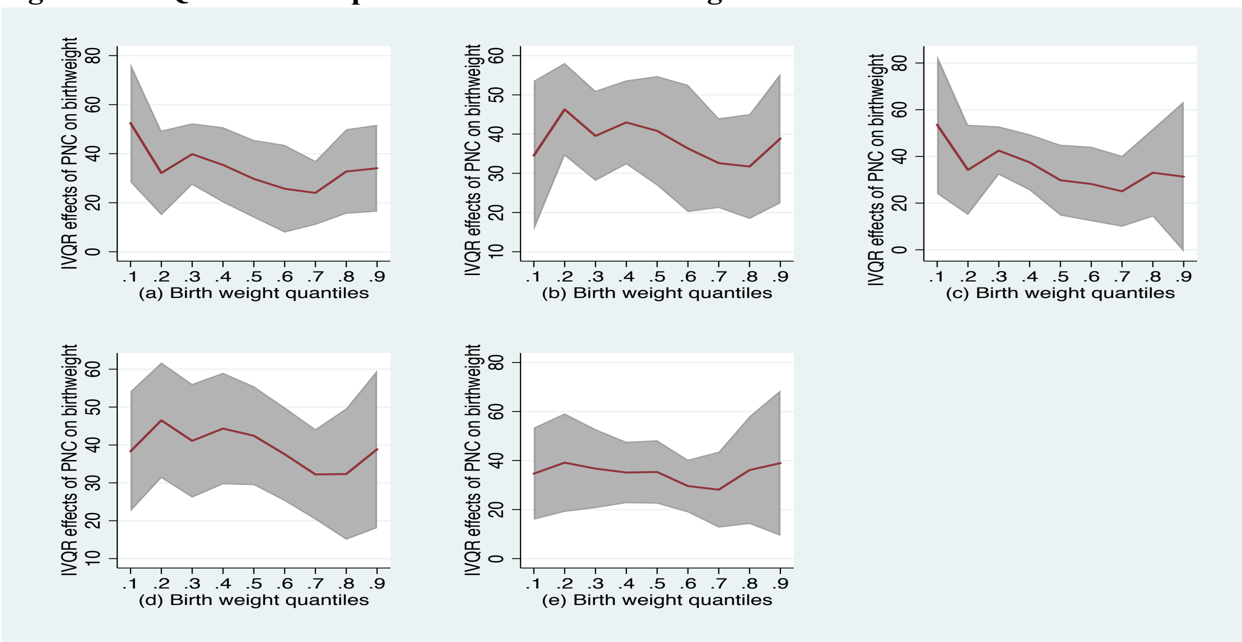


Note: Bootstrapped standard errors based on 100 replications. The y-axis represents changes in birth weight measured in grams. Control variables include the mother's age, the square of the mother's age, mother's education, gender, birth order of the child, and state fixed effects. Shaded areas show 95% confidence intervals.

Consistent with the OLS results, the QR results in Figure 1 demonstrate that prenatal visits and birth weight are positively correlated at all quantiles of birthweight. While the relative increase in birth weight due to additional PNC is statistically significant at conventional levels of significance, the magnitude is relatively small. The effect size ranges from 3-11 grams, which at the mean birth weight of 3,204 grams corresponds to an increase in birth weight by 0.1-0.3 percent. In general, the correlation between prenatal visits and birth weight appears to be higher at the lower quantiles compared to higher quantiles of the birth weight distribution (figure 1). As the models in Figure 1 do not control for potential endogeneity, these results cannot be interpreted as causal. The results that take into account the potential endogeneity related to selection into prenatal care are reported in Figure 2. In what follows, only the results reported in Figure 2 will be considered since they are plausibly causal, unbiased, and consistent with the objective of this study.

The IVQR results reported in Figure 2 confirm that the causal effects of PNC on BW would have been underestimated if endogeneity were not addressed since the QR results are smaller (Figure 1) in magnitude compared to IVQR results (Figure 2). The full results for the main specification are reported in Table II. Similar to the QR results, the effect of a prenatal visit on birth weight is positive and statistically significant at all quantiles of birth weight distribution in the IVQR model.[2]

Figure 2. IVQR effects of prenatal care on birth weight



Note: Bootstrapped standard errors based on 100 replications. The y-axis represents changes in birth weight measured in grams. Control variables include the mother's age, the square of the mother's age, mother's education, gender, birth order of the child, and state fixed effects. Shaded areas show 95% confidence intervals.

The positive impact of an additional prenatal visit is higher at the lower quantile of birth weight distribution and decreases almost monotonically moving toward the higher quantile of the distribution. Results in panels A-E in Figure 2 show that the effect of an additional prenatal visit ranges from 24 grams (0.7 quantiles, panel A) to 54 grams (0.1 quantiles, panel C). The increase in birth weight for infants at the 10^{th} quantile in model C (54 grams) is 1.8 times the weight gain at the 90^{th} quantile (31 grams) of birth weight distribution. At the mean birth weight of 3204 grams, the IVQR results imply an increase of 1.7% due to an extra prenatal visit at the 10^{th} quantile of birth weight distribution; however, birth weight increases by 1% at the 90^{th} quantile. This is consistent with the epidemiological evidence that the marginal benefits from prenatal visits occur in infants who are relatively at risk and less healthy.

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[2]The effects of other confounding variables were overall consistent with the previous literature and economics theory except for mother's education. As expected, mother's age, birth order, male infants were positively associated with birth weight. The association between mother's education and birth weight is mixed.

Column (10) in Table II reports the 2SLS estimate of the effect of PNC on the birth weight of the infants. It can be seen that the 2SLS estimate for prenatal care is positive in sign and is statistically significant. show that the incremental effect of a prenatal visit on birthweight is 42 grams, which amounts to a 1.3% increase in birth weight due to an extra prenatal visit. The results from this study are comparable to findings in studies conducted in South America and Azerbaijan, although these studies differ in sample size and empirical specifications. For instance, Wehby *et al*. (2009) estimated an effect of 77 grams per PNC visit at the 0.1 quantiles but the marginal effect of PNC on BW was only 10 grams at the 0.9 quantiles in Argentina, and it was statistically insignificant at the 0.9 quantiles. The results from the study in South America is similar, for instance, the gains associated with prenatal visit ranged between 50 and 57 grams in these countries, which is in line with the findings in. our study. In Azerbaijan, the 2SLS estimate was 26 grams, which is lower than our result of 42 grams, implying that in addition to the number of prenatal visits, the quality of prenatal care may also affect birth weight (Habibov and Fan 2011). The variation in the birthweight effect across countries may highlight the importance of quality of healthcare system in resource-constrained countries.

The magnitudes of the estimated coefficients are non-trivial and economically meaningful. One way to put the results into perspective is to consider them in the context of national guidelines on the adequacy of prenatal care in Mexico. The Mexican health ministry recommends at least five prenatal visits and if they meet this goal, our results imply an average increase of 270 grams (54 grams x 5 PNC visit) at the 10^{th} quantile of birth weight distribution (equivalent to 10% increase), which is likely to reduce the health expenditure as low birth weight infants contribute to substantial medical and non-medical cost.

In a robustness check, we estimate interquantile range regression to examine if the differences in the PNC effects on birthweight across birthweight quantiles are statistically significant. The findings are reported in Table III. The estimates in each column present the difference in coefficients at different quantiles. For example, the estimates in column (1) show the difference in the effect of PNC on birthweight at the 50^{th} and the 10^{th} quantile and it also shows the statistical significance of this difference. The results show evidence of differential effects of prenatal care on the 50^{th} & 10^{th}, 60^{th} & 10^{th}, and 70^{th} & 10^{th} quantiles, but lacks statistical significance at the higher quantiles of birthweight distribution. For instance, the difference between 80^{th} and 10^{Th} quantiles is not statistically significant although the difference in magnitude is as large as 19.8 grams. The negative sign of the coefficient implies that the effect of the PNC is higher at the lower quantile compared with higher quantile. Results in column (1) show that the effect of PNC on birthweight at the 10^{th} quantile is 22.7 grams larger than the effect size at the 50^{th} quantiles and the difference in the effect size is statistically significant at 5% level of significance.

5. Conclusions

The study examined the impact of the prenatal visit on birth weight in Mexico using instrumental variable quantile regression, which accounts for unobserved as well as distributional heterogeneity. While mean effects are important, we believe that quantile results are important to understand the marginal effects of prenatal visits on birth weight at the lower and higher distribution of birth weight. We find evidence of heterogeneous effects of a prenatal visit on birth weight, with the strongest effects at the lower quantile compared to the higher quantile of birth weight distribution.

Our main findings are robust to alternative model specifications. From a policy standpoint, our results indicate that mothers who are at risk of delivering low birth weight babies could benefit the most from increased use of prenatal care in Mexico. Policymakers should focus on infants at the bottom quantile of birth weight distribution in order to reduce the welfare cost of low birth weight. Our results also call for the need for policymakers to ensure access to quality prenatal care services to all pregnant women as it improves birth outcomes of newborns in Mexico.

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Appendix

Table II. Instrumental variable quantile regression (IVQR) effects of prenatal care on birth weight

	OLS	Quantiles									2SLS
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
First-stage results											
Married						0.665***					0.665***
						(0.031)					(0.038)
F-statistics											305.72
Prenatal care visit	8.04***	62.25***	55.93***	40.73***	38.62***	36.52***	32.39***	27.96***	34.13***	33.09**	41.95***
	(0.714)	(12.48)	(8.36)	(6.02)	(6.59)	(7.62)	(7.83)	(10.22)	(8.38)	(14.19)	(4.88)
Mother's age	24.46***	9.53*	6.13	9.47***	7.57**	9.56***	11.76***	12.94***	10.52***	11.90**	12.78***
	(1.85)	(5.65)	(3.81)	(2.94)	(3.60)	(3.42)	(3.94)	(4.56)	(3.730	(5.67)	(3.22)
Mother's age square	-0.413***	-0.334***	-0.231***	-0.236***	-0.186***	-0.207***	-0.225***	-0.221***	-0.176***	-0.177**	-0.274***
	(0.034)	(0.079)	(0.053)	(0.043)	(0.054)	(0.047)	(0.057)	(0.061)	(0.054)	(0.079)	(0.049)
Mother's education	13.16***	-43.17**	-32.81***	-11.10	-4.81	3.35	7.33	11.71	4.39	0.206	-21.87**
	(7.01)	(17.12)	(11.25)	(8.53)	(7.69)	(9.47)	(8.45)	(10.66)	(10.09)	(16.53)	(9.48)
Birth order	16.61***	36.82***	38.28***	31.37***	31.04***	32.19***	31.49***	30.18***	32.75***	34.95***	32.56***
	(1.56)	(5.82)	(4.38)	(3.04)	(3.41)	(4.16)	(3.74)	(5.33)	(4.48)	(6.62)	(3.56)
Gender (male)	76.22***	29.01***	58.61***	69.04***	74.67***	86.71***	95.50***	102.06***	107.96***	114.30***	77.67***
	(2.86)	(4.85)	(3.10)	(2.62)	(2.69)	(2.92)	(2.39)	(3.01)	(3.41)	(5.33)	(2.61)
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	129,850	129,188	129,094	129,094	129,094	129,094	129,094	129,094	129,094	129,094	129,188

Notes: Robust standard errors, clustered at the state level, are reported in parentheses. Quantile regression standard errors are bootstrapped (100 replications with replacement). Statistical significance: *** 1%, ** 5%.

Table III. Robustness checks

	Interquantile Regression (0.50-0.10)	Interquantile Regression (0.60-0.10)	Interquantile Regression (0.70-0.10)	Interquantile Regression (0.80-0.10)	Interquantile Regression (0.90-0.10)
	(1)	(2)	(3)	(4)	(5)
Prenatal care visit	-22.76**	-26.80**	-28.49**	-19.77	-18.44
	(10.69)	(12.98)	(12.32)	(13.10)	(15.93)

Note: Bootstrapped standard errors based on 100 replications. Controls include the mother's age, the square of the mother's age, mother's education, gender, and birth order of the child. State and year of birth fixed effects are included in all models.