Investing in the Womb: Identifying Gender Discrimination through the Lens of Prenatal Ultrasounds

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ABSTRACT

In utero is a critical period of human development during which parents act on children's behalf in health investments. These investments may have a profound impact on the life trajectory of a child. We investigate whether parents in Northern China who choose to carry the pregnancy to term allocate resources differently between their sons and daughters over the course of pregnancy after the sex of the child is disclosed to parents. Using unique and large-scale hospital electronic records of prenatal ultrasound scans and birth outcomes as well as a longitudinal survey of parents' health behavior during pregnancy, we estimate how parental health behaviors and prenatal health investments change after parents gain access to gender information from post-20 gestational week ultrasound scans. In addition to the state-of-the-art difference-in-differences model, we employ a novel fetus fixed effect model to identify shifts in prenatal investments when information on child gender is disclosed. We document sex-selective prenatal investments as an early channel through which parents practice discriminatory behavior. We show that parents favorably shift certain parental health investments when pregnant with a boy. Specifically, the chance of exposure to passive smoking decreases while more mothers take nutrient supplements when parents expect boys compared to girls after receiving a post-20th gestational week ultrasound scan. Preferential prenatal treatment of males is greater for areas with stronger son preference. A set of key placebo tests using pre-pregnancy and early pregnancy behaviors reassure us that our identified effects are likely causal. Our findings have implications for eliminating gender discrimination and improving maternal and child health in the earliest stage of life. These findings also call for utilizing the window of opportunity during pregnancy to more effectively promote smoking cessation.

Key Words: In Utero, Parental Health Investments, Ultrasound Scans, Gender, Son Preference

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INTRODUCTION

Economic studies have substantially detailed the impact of investment in early childhood on adult outcomes. Family environments and parental behaviors towards children during early childhood play a large role in the development of children's skills before they enter formal schooling (Francesconi & Heckman, 2016). Evidence has shown that cognitive and socioemotional skills developed in early childhood can affect future occupation and level of income, the probability of marrying and divorcing, voting behavior, adult health, and the likelihood of receiving welfare. Furthermore, gaps in cognitive and socioemotional skills, such as across socioeconomic statuses, have been well documented (Francesconi & Heckman, 2016). While it has been proposed that genetics may partly explain discrepancies in skills among children, evidence strongly supports that other factors including parenting style also shape skills. Furthermore, these other factors may turn on or enhance the expression of certain genes through epigenetics, indicating that environmental influences in early childhood may be heritable and thus perpetuate inequality or discrimination in society (Francesconi & Heckman, 2016).

Critical periods exist for development during childhood. It has been well recognized that the nine months in utero is the most critical period in life, shaping future health and human capital trajectories (Almond & Currie, 2011; Doyle, Harmon, Heckman, & Tremblay, 2009). Inequality in early childhood development therefore can begin *in utero* as fetuses are exposed to differing prenatal environments. For example, exposure to maternal undernutrition *in utero* leads to a higher probability of developing chronic diseases such as cardiovascular disease and type-2 diabetes (Lee, 2015). In this way, parental health behaviors and investment in the health of their infant *in utero* could impact the future of their children. However, much of the economic literature on parental behavior and investments in children has had a postnatal focus versus a prenatal focus. For example, differential parental investment in cognitive stimulation and emotional support of low birth weight infants compared to normal birth weight infants based on maternal education and family income has been well described (Restrepo, 2016).

The gap of knowledge on parental behavior and health investments in infants prenatally is only beginning to be filled. Inequality during the prenatal period could take the form of gender discrimination. Gender discrimination in prenatal investments can be studied by looking at changes in parental health behavior and health investments during pregnancy after discovering the gender of the fetus using ultrasound technology post-20 weeks of gestation. Cultural preferences for males over females in East and South Asia have persisted despite economic growth and social changes (M. D. Gupta et al., 2003). Due to these cultural preferences, economic literature has found that the diffusion of ultrasound technology in India and China has contributed to practices of sex selection for male infants over female infants in these countries (Anukriti, Bhalotra, & Tam§, 2015; Chen, Li, & Meng, 2013). Though it is illegal to reveal the gender of the infant to parents in both countries because of sex selection, it is estimated that there are between 30-70 million “missing girls” in India and China due to abortions of female fetuses (Bharadwaj & Lakdawala, 2013).

Because of the limited data available, studies have primarily looked at sex ratios and mortality rates to indirectly find evidence that parental health behaviors and health investments prenatally may differ based on the gender of the child in these countries. For example, evidence has shown skewed sex ratios occur during famines and that mothers in good conditions are more likely to give birth to sons whereas mothers in poor conditions are more likely to give birth to daughters (Song, 2012). This indirectly indicates a preference for gender by parents as well as differing parental behavior and parental health investment prenatally.

The following study aims to find more direct evidence for gender preference in prenatal investment in the context of the China Birth Cohort Study (CBCS). It contributes to the literature in four ways. First, we add another context for studying the investment in the “black box” of *in utero* development to the limited literature. Second, we investigate parental health behaviors and investments not considered by other studies. Third, we analyze the results with a robust fixed effects strategy not present in the literature to date. Lastly, the results of the findings of this study have policy implications for reducing gender discrimination against females during the prenatal period and for smoking cessation promotion.

Few prior studies have aimed to find direct evidence for differing parental behavior and health investments based on gender. Lhila and Simon looked at prenatal health decisions by parents in the U.S., with special attention to decisions made by Indian and Chinese immigrant parents (Lhila & Simon, 2008). Interestingly, they found that sex ratios of infants among Indian and Chinese immigrants are consistent with sex-selective abortions against females. However, among parents who carried their pregnancies to term, there was no significant difference in prenatal health investments for female and male infants in neither the Indian and Chinese immigrant population nor in the U.S. population as a whole (Lhila & Simon, 2008).These findings were determined by interacting gender with ultrasound receipt, a similar strategy employed in the following paper. Therefore, by comparison to the findings in the U.S., the following paper adds to the literature by contributing to an understanding of how early childhood development may be impacted in different countries because of differences in cultural, social, political, or economic environment.

Bharadwaj and Lakdawala examined parental behaviors and prenatal sex discrimination in India as well as in other countries including China (Bharadwaj & Lakdawala, 2013). The study found that parents invest in more prenatal care, such as prenatal visits and tetanus shots, when expecting a male versus a female infant. While the study did find parents in China expecting a male invested more in prenatal care, the authors do not investigate other parental health behaviors could change based on the sex of the child including those related to smoking, alcohol consumption, diet, exercise, and more. In the following paper, we analyze these parental behaviors of both the father and mother as both contribute to overall investment in the health of the expected infant. Therefore, the following paper adds to the literature by understanding further the shifts in health behavior and investment by parents using data from the CBCS.

Bharadwaj and Lakdawala acknowledge several identification problems in their estimation strategy, including son preference-based fertility stopping rules. These rules determine the strength of son preference a family has based on family size and the gender of the most recently born child. Additionally, the data included only live births, excluding sex-selective abortions that could potentially have caused different types of biases (Bharadwaj & Lakdawala, 2013). These identification problems also exist in the data from China because, despite the One-Child Policy that restricted families to having only one child, many parts of China were exempt from the policy and therefore families could have multiple children. Sex-selective abortions are also not included in CBCS data, though history of spontaneous and medical abortions of the mother is recorded. Because of the difficulty of obtaining information on abortion, using only live births is common in the literature.

To overcome these identification problems, Bharadwaj and Lakdawala used methodology proposed by Barcellos, Carvalho, and Lleras-Muney. The idea behind the methodology is that the last child of a family is “young enough” in the pregnancy so that parents do not have time to adjust their fertility based on the gender of the child (Barcellos, Carvalho, & Lleras-Muney, 2014). The following paper also uses this strategy to remove the effect of latent gender preference parents may have.

Another issue with the identification strategy used by Bharadwaj and Lakdawala as well as other studies on this topic is the use of sibling comparisons, such as sibling sex ratio, as a control for trends that occur between births. However, sibling comparisons may not capture several other confounding variables that change between births, such as parenting styles or changes in parental gender preference. In the following paper, the use of fetus fixed effects as a control mitigates this problem. By removing individual heterogeneity, we attain more robust estimates of changes in parental health behavior and health investment during pregnancy in the CBCS data.

Our results find that parents do indeed favorably shift some parental behaviors and investments after discovering they will have a boy compared to a girl. Specifically, the rate of exposure to passive smoke (smoke in the environment) and the rate of the father smoking in front of the wife decreased while the rate of mother taking nutrient supplements increased more for boys than girls after an ultrasound after the 20th week, which gave parents access to the gender information. These findings have policy implications for smoking cessation for fathers and for interventions that can be implemented to eliminate gender discrimination during the prenatal period.

The following paper first presents the theory of prenatal investment with a gender preference component, secondly describes the data in the CBCS, thirdly details the models employed to analyze the CBCS, fourthly outlines the results, and lastly discusses the implications of the findings.

THEORY

We adopt the theoretical framework detailed by Lhila and Simon that parents derive utility from investing in the prenatal health of their expected infant because they are concerned with the overall welfare of their child (Lhila & Simon, 2008). In this framework, the degree of utility they derive may differ based on gender preference. Therefore, the maximization problem outlined by Lhila and Simon of expecting parents is as follows:

$$\text{Max}[U\{G, H(I), X) \mid e, c\}]$$

$$s.t.\ W = P_I I + P_X X$$

Maximum utility is driven by G, the gender of the child, $H(I)$, the health of the infant at birth as a function of prenatal investment I, and all other goods, X, that confer utility to parents. The economic and cultural conditions (e, c) determine how gender contributes to utility. The utility maximization problem is subject to the budget constraint where W, family income, equals the costs of prenatal investment, $P_I I$, and the costs of all other goods, $P_X X$, parents purchase that are unrelated to prenatal investment.

The economic and cultural conditions in China lead us to suspect that parents have a gender preference for males over females. Economically, parents often prefer male children because they believe males will provide more economic security for the family, especially in old age. Culturally, because of the structure of kinship systems, girls confer value to the family they marry into, not necessarily their own family (D. M. Z. Gupta, Jiang Bohua, Li Zhenming, Xie Chung, Woojin Hwa-Ok, Bae). Furthermore, the One-Child Policy, enacted in 1979 until 2005, added more pressure for parents to express their gender preference. Though exemptions existed that allowed families in rural areas to have another child if the first born is female to reduce sex-selection (Pletcher, May 26, 2016), parents may have increased the expression of the gender preference for males even more, leading to an increased likelihood that higher-order births would be male.

We expect parents to adjust their prenatal investment after discovering the gender of their expected child so as to maximize their utility based on the gender of the child. The gender can be determined by ultrasound by the 20th week of gestation. We assume that by receiving an ultrasound at the gestational week 20, parents have access to gender information. Before the 20th week of gestation, we expect parents to have no difference in prenatal investment based on gender because they do not know the gender information. However, after disclosure of gender at an ultrasound post-20th week of gestation, parents with gender preference may increase prenatal investments when expecting males relative to parents expecting females. Likewise, parents expecting females may decrease prenatal investments relative to parents of males. If parents who elect to have sex-selective abortions capture all the parents who exhibit gender preference for males, we then expect no shift in prenatal investments between parents of males and females who decide to carry the pregnancies to term after the 20th week of gestation. However, as policies and programs have been introduced to reduce sex-selective abortions, we hypothesize that gender preference against females may still be expressed by discriminatory prenatal investment against females whose births are carried to term.

DATA

The data in this study are drawn from a major hospital in a province in Northern China that serves eight urban districts and rural counties nearby. Expecting mothers were required to fill out a questionnaire distributed at the hospital each time during their visit to receive the ultrasound scan. The data was collected from 2009 to 2012 and has multiple observations for the same pregnancy throughout time until birth, which are identified under the same child's ID.

There are a total of 20,938 observations that follow the pregnancies for 7,778 infants. The data contains variables for the gestational week of ultrasounds as well as parental health behaviors, prenatal health investments, and control variables such as parent's education and family income that are all used in this study. Summary statistics of variables used in this study are included in the appendix (Tables A1, A2, A3). A histogram of the frequencies of gestational week at the record of ultrasound (Figure A1) shows that most ultrasounds were performed during the second (gestational weeks 13 to 27) and third trimesters (gestational week 27 to week of delivery).

To determine if the data contained underlying preferences for males over females, we calculated the probability of having a male infant and the sex ratios of males to females in the data. The results in Table 1 show that the probability of having a male infant increased as birth order increased. Similarly, the sex ratio became more skewed from the natural ratio of 1.05 males to females as birth order increased (WHO 2017). The skewed sex ratios are visually depicted in Figure 1. These results suggest that a preference for male infants exists in the data, especially at higher birth orders. These results match expectations as families with gender preference often continue to have children until they have a male child. Furthermore, as an exception to the One-Child Policy in China, families in rural areas could have a second child if their first-born was female or suffered from mental or physical disabilities.

In this study, fetus exposure to smoke is an important indicator of prenatal investment. 'Passive smoking' (exposure to environmental smoke), 'father smoking in front of the wife', and 'father currently smoking' were dummy variables measured each trimester. To first see if a pattern for exposure to smoke arose over the course of pregnancy, we found the average of these variables for each trimester (Table 2) and plotted these numbers (Figure 2). We found that the exposure to passive smoke and rates of the father smoking in front of the wife decreased in the second and third trimester whereas the 'father currently smoking' increased in the second trimester and stayed at the relatively the same level in the third trimester. The level of father's smoking is qualitatively close to the overall rate of smoking in China for males in 2012 at 49% (World Bank, 2016). This suggests that during pregnancy, parents increased prenatal investment by the second trimester by reducing exposure to smoke. However, the persistent levels of fathers currently smoking indicate the addictive quality of smoking. Though fathers may have been smoking less in front of the developing fetus, they maintained and even increased the rate of smoking by the second trimester. The increase in the second trimester could have been because fathers' of girls know the gender by the end of the second trimester. If they had a gender preference, they may not have tried to reduce their smoking rates compared to if they knew they were expecting a boy.

MODEL

1. Difference-in Differences Model

We employ a difference-in-differences model to analyze shifts in prenatal investment of parents of males versus females after they discover the gender of their children. For prenatal investments with multiple observations, such as the likelihood of exposure to passive smoke and of the mother taking nutrient supplements, we use the following specification:

$$(1)\quad I_{ij} = \beta_0 + \beta_1 Gender_i + \beta_2 GestWk20_j + \beta_3 Gender_i * GestWk20_j + \eta \boldsymbol{X}_{ij} + \varepsilon_{ij}$$

where I is the measure of prenatal investment for an individual infant i when an ultrasound was done at gestational week j. $Gender_i$ is a dummy variable that equals 1 when the gender of i is male and 0 when female. $GestWk20_j$ is a dummy variable that equals 1 if the ultrasound performed at week j is greater than or equal to 20 weeks and 0 if less than 20 weeks. $\boldsymbol{X}_{ij}$ is a vector of covariates, including year, month, parent's education, parent's age, parent's height, income, and district. The coefficient β_3 on the interaction of $Gender_i*GestWk20_j$ captures the difference in prenatal investment for male versus female infants after an ultrasound is done at or after gestational week 20 compared to before gestational week 20. If the estimate of β_3 shows statistical significance, parents are shifting their prenatal investment based on gender.

However, for prenatal investments with only one-time observation throughout the pregnancy, such as number of ultrasounds and maternal weight gain, our difference-in-differences setting is restricted to a first difference model. Utilizing the following specification to find differences in investment by gender

(1) $I_i = \beta_0 + \beta_1 Gender_i + \eta \boldsymbol{X}_j + \varepsilon_i$

As for the specifications for multiple observations, $Gender_i$ is equal to one when individual i is male and zero when female and $\boldsymbol{X}_j$ represents the control variables. The estimate of β_1 gives the difference in prenatal investment I between boys and girls.

2. Difference-in-Differences Model in the Longitudinal Setting

To obtain a more robust understanding of differences in prenatal investment after gender disclosure, we used a fixed effects model to control for individual heterogeneity during the pregnancy of each child. Instead of comparing parental investments across children that could be confounded by factors such as preference, we compare within each individual fetus but in different stages of the fetal development. It is most plausible that those potential confounders are constant between the small gap of days or weeks and therefore are removed. We set the panel variable as the child's ID and the time variable as the record number of the child. We run the following regression for males and females separately:

(2) $I_{it} = \beta_0 + \beta_1 GestWk20_t + \alpha_i + \eta \boldsymbol{X}_{it} + \varepsilon_{it},\ t = 1, \ldots, T$

where I is the measure of prenatal investment for an individual infant i at ultrasound record number t. The majority of the mothers of the infants had two ultrasound records, though some have up to four. $GestWk20_t$ is the dummy variable for whether at time record t, the mother had received an ultrasound at or after gestational week 20. The unobserved time-invariant fixed effect is denoted as α_i and X_{it} represents the vector of control variables. The estimate of β_1 determines how prenatal investment changes after parents have access to gender information. One estimate is determined for males and another is determined for females. Comparison of the two estimates provides insight into how prenatal investments differ between the two groups after parents discover the gender of the child.

RESULTS

1. Simple Difference-in-Differences Analysis of Prenatal Investment

We first utilized a simple difference-in-differences with no controls to analyze variables with multiple observations over the course of pregnancy (Table 3a). We analyzed likelihood of fetus exposure to passive smoke, the father smoking in front of the wife, the father currently smoking, the father drinking alcohol, and the mother taking nutrient supplements as well as the total hours of exercise and diversity of diet (number of types of food) of the mother. Of those who carried pregnancies to term, mothers of male infants are less likely to be exposed to passive smoking (6.6 percentage points less) compared to parents of female infants after they had access to gender information. The increase in likelihood (43.2 percentage points) of taking nutrient supplements for mothers of males compared to females was also highly significant. The decrease in likelihood of the father smoking in front of the wife and the father currently smoking in general for males over females after parents could discover the gender of the child were significant.

We then performed the same simple difference-in-differences analysis but restricted the sample to infants whose mother had received one or more ultrasounds both before and after the 20th week of gestation (Table 3b). The decreased likelihood in exposure to passive smoking for male infants compared to female infants was significant, but not highly significant as in Table 3a. The greater likelihood of mothers of males compared to those of females taking nutrient supplements after an ultrasound in the 20th week maintained high significance. Fathers smoking in front of the wife had a weaker significance compared to Table 3a and father currently smoking was not significant. Though the significance levels vary, Table 3a and 3b both suggest that a simple analysis of the data uncovers parental prenatal investments favoring males over females after gaining access to the gender information from ultrasounds post-20 weeks of gestation.

We also analyzed simple differences in one-time observations between genders without controls (Table 4) by collapsing the data by the identification number of the child. However, none of the simple differences for one-time observations revealed gender preference in prenatal investments for males over females.

2. Difference-in-Differences Analysis of Prenatal Investment with Controls

We next performed a more rigorous difference-in-differences analysis for multiple observations for all births, first order birth, and higher order births, controlling for year, month, parent's education, parent's age, parent's height, family income, and district (Table 5). We found that some of the estimates from the simple analysis remained statistically significant, while others did not. As expected from the simple analysis, the greater likelihood (43.9 percentage points) of mothers of boys taking nutrient supplements compared to mothers of girls after an ultrasound post-20th week of gestation versus before pre-20th week was highly significant. The greater likelihood was also statistically significant for first order and higher order births. The greater decrease in likelihood for exposure to passive smoking for male infants had weak significance for all births and other birth orders whereas the greater decreased likelihood of the father smoking in front of the wife for males was highly significant only for higher-order births. The greater decreased likelihood of the father drinking alcohol for male infants was weakly significant for all births and significant for first order births. This result is unexpected as the father drinking alcohol should not have a direct negative impact the development of the fetus and therefore, would not be considered a prenatal investment that parents would decide to alter based on gender.

We next analyzed differences in gender for one-time observations with controls, additionally looking at outcomes by birth order (Table 6). For higher-order births, maternal weight gain was highly significantly greater (0.46 kg). However the magnitude of this correlation is negligible.

3. Fixed Effects Analysis of Changes in Prenatal Investment

We then used the fixed effects model to more robustly estimate change in prenatal investment based on gender for multiple observations, which controlled for heterogeneity throughout pregnancy of each infant (Table 7). Unlike the difference-in-differences model that provided a comparative estimate for prenatal investment between genders, the fixed effects model gave the direction of the changes in magnitudes for prenatal investment for each gender. Because of the robustness of the fixed effects model, a difference in direction of the estimates between males and females indicates gender preference in prenatal investments. For example, while the likelihood of the mothers taking nutrient supplements increased for boys for all births after receiving an ultrasound in gestational week 20+, mothers of girls for each birth order measured had a declined likelihood. Similarly, while the likelihood of exposure to passive smoking and the father smoking in front of the wife decreased for boys in all births after parents had access to gender information, the likelihood increased for girls. These results confirm the increased likelihood of prenatal investment measures, specifically nutrient supplements intake and decreased exposure to smoke, for boys compared to girls after disclosure of gender during pregnancy.

4. Changes in Prenatal Investment by Socioeconomics Status

To determine if gender preference and prenatal investment had a stronger correlation based on socioeconomic status, difference-in-differences estimates for multiple observations were determined based on mother's educational attainment and the family's monthly income before pregnancy (Table 8). Educational attainment of the mother was grouped into two categories with the cutoff at whether the mother obtained higher education. The decrease in likelihood for passive smoking exposure for males compared to females after parents had access to gender information was significant only for infants whose mothers did not obtain higher education. However, the highly significant greater likelihood of mothers taking nutrient supplements when discovering the expectance of a boy compared to a girl was present for both categories of mother's education. Whereas the number of hours the mother exercised per trimester decreased with weak significance for boys compared to girls after gender information could be disclosed for mothers with no higher education, the number of hours increased with weak significance for mothers with higher education.

A consistent pattern could not be determined from the estimates by family monthly income, though some observations were prominent. First, decreased likelihood of passive smoking exposure for boys compared to girls after gender disclosure was highly significant for only the lowest income group (<1000 yuan per month). Second, increased likelihood of nutrient supplements for boys compared to girls after gender disclosure has some significance level for all income groups. Third, the father smoking in front of wife decreased in likelihood after discovering the gender was male with high significance for the middle-income group making 2000 to 3000 yuan per month. Lastly, the likelihood of the father drinking alcohol decreased with high significance for male infants versus female infants after gender exposure only for the second highest income group (4000-5000 yuan per month). Though these results do not establish a clear pattern of gender preference in prenatal investments by income group, they suggest that some income groups may exhibit gender preferences for certain prenatal investments compared to others.

To test if there was selection for mothers in certain socioeconomic groups to obtain ultrasounds before 20 weeks of gestation, we determined the likelihood of receiving a pre-20th week ultrasound based on the mother's educational attainment and the family's income level (Table A4). We found that there was no selection by income group. However, mothers who attended senior high school or graduate school had a significantly greater chance while mothers who attended college had a weakly significantly greater chance of receiving an ultrasound pre-20th week compared to mothers who received no education. In this way, there exists some selection for mothers of higher education levels to obtain an ultrasound before the 20th week in the data. This may suggest that the majority of the shifts in parental behavior and investment before and after the 20th week of gestation this study analyzed occurred during the pregnancies of higher educated mothers.

5. Placebo Tests

We conducted a series of placebo tests (Table 9 and 10) to determine if gender discrimination in prenatal investment occurred before pregnancy, within the time period before the 20^{th} week gestation when the gender is unknown, or within the time period after the 20^{th} week of gestation to birth when gender is already known. We expected to not find significant differences in prenatal investment between genders during these time periods. Test 1 regressed prenatal investments on gender restricted to before the 20^{th} week of gestation (Table 9). The only strongly significant finding is that before the 20^{th} week of gestation, mothers of boys' likelihood of taking nutritional supplements was 37.2 percentage points less than mothers of girls. This result shows that we may be underestimating the increased likelihood of taking nutrient supplements after mothers discover they are expecting a boy compared to a girl. The second test used variables that measured behaviors before the pregnancy, during which the gender of the child would not have been known (Table 9). As expected, the majority of the results for the test were not significant and the magnitudes of the significant results were negligible in magnitude.

The last placebo test restricted the sample to after gestational week 20 for the fixed effects model and regressed variables with multiple observations on gestational week 26 or week 30. During this time period, parents already had access to the gender information of the fetus and therefore, we did not expect them to significantly change their behavior based on gender. For the regression on week 26, the magnitude of the estimates for boys and girls are in the same direction except for diversity of diet, however these estimates are negligible in size. For the regression on week 30, the estimates for boys and girls were in opposite directions for all variables except nutritional supplements. However, the estimates were very small in magnitude, indicating that there was not a great change in prenatal investment based on gender in the weeks after gestational week 20.

DISCUSSION

Parents with gender preferences may differentially invest in their expected child during the course of prenatal development. This study aimed to understand how parental health behaviors and prenatal health investments change when parents discover the gender of their expected child after an ultrasound at the 20^{th} week of gestation. We analyzed this question in the context of the China Birth Cohort Study (CBCS) that contained data for ultrasound records and prenatal investment measures for children born between 2009 and 2012. We first found that the data had skewed sex ratios of males to females, especially at higher birth orders, which indicated gender preferences for males in the sample. We also noted that the smoking rates of the father in front of the wife and exposure to passive smoke decreased each trimester, but that the overall rate of fathers smoking stayed relatively high, increasing in the second trimester.

We found evidence from both the difference-in-differences and fixed effects analysis that parents shifted their health behaviors and prenatal investment after gaining access to gender information in a way that favors males versus females. After an ultrasound at the 20^{th} week of gestation compared to before, the likelihood of exposure to passive smoking and the likelihood of the father smoking in front of the wife decreased whereas the likelihood of mothers taking nutrient supplements increased when expecting a male versus a female infant. The increased likelihood of nutrient supplement intake for mothers of males was consistent across the educational attainment level of the mother and all income groups. The decreased likelihood of exposure to passive smoking was significant for males compared to females whose mothers had no higher education and families in the lowest income group. We also tested prenatal investments with one-time observations such as maternal weight gain, but did not find strong evidence that parents shifted these measures of investment after gaining access to gender information. A series of placebo tests strengthened the validation of our findings.

Multiple factors could have led to underestimates in our findings. First, the structure of the data may have led to imperfect categorization of some ultrasound records in the control group instead of the treatment group. For example, because the measurements of parental health behavior were noted for each trimester, variations within a trimester were excluded. This may have contributed to underestimation of the results, especially because the majority of the ultrasound records occurred within the second or third trimester. Secondly, the noise in ultrasound scans could have also affected the findings. Though ultrasound scans can determine gender with at least 95% accuracy, the accuracy also depends on the skills and training of the physician.

Thirdly, we assume that by receiving an ultrasound after the 20^{th} week, the physician discloses the gender to the parents. However, not all parents may access the gender information and therefore would not be able to change behavior and investment based on the gender. The results of this study, however, suggest that most parents are accessing gender information and changing behavior and investment. Fourthly, physicians may also have a role in intervening with prenatal health and maternal health behaviors that may mitigate investment based on gender preference. Lastly, parents who elect to have gender-selective abortions for females may be capturing the largest differential in prenatal investment preference between males and females. In this study, we analyzed only pregnancies that were carried to term and therefore may be missing parents who have the strongest gender preference who proceed with sex-selective abortions.

Despite these limitations, this study has several implications. First, the findings reaffirm the need to reduce inequality for prenatal investment by gender because the prenatal period is critical to returns in adulthood. Secondly, the study specifies health behaviors of both mothers and fathers, which are both important policy applications. While investment in early childhood often focuses on maternal investment, paternal investment, such as the father smoking in front of the wife, is also influential and often overlooked. Furthermore, reduced rates of fathers smoking in front the wife throughout each trimester suggest pregnancy may be an optimal time for smoking cessation programs for fathers. Smoking cessation programs could have a big impact during this time period because fathers seem to be inclined to reduce their expected child's exposure to smoke. Additionally, expecting fathers are relatively young and smoking cessation at younger ages leads to high returns for later in life. Therefore, reducing smoking rates during pregnancy of fathers at least around their wives, though ideally all the time, could have a multigenerational effect by improving the health of both the father and the child. According to this study, decreased exposure to the father smoking should be particularly emphasized for parents expecting girls.

Lastly, other policy implications could arise from the findings of this study. Interventions in clinics to promote positive prenatal investment equally for both girls and boys could help mitigate inequalities. For example, education about exposure to passive smoke, especially for mothers without higher education and families with lower income expecting a girl, could help close the gap of exposure to environmental smoke with families expecting a boy. Similarly, interventions to increase the uptake of nutrient supplements for mothers of girls could be implemented. These interventional policies may prove to be more effective than the current law that forbids disclosure of gender from an ultrasound to reduce gender discrimination. The evidence in this study finds that gender discrimination in prenatal investments against female infants occurs despite the law and calls for a need for creative solutions to equalize prenatal investment between genders.

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Figure 1: Sex Ratios by Birth Order

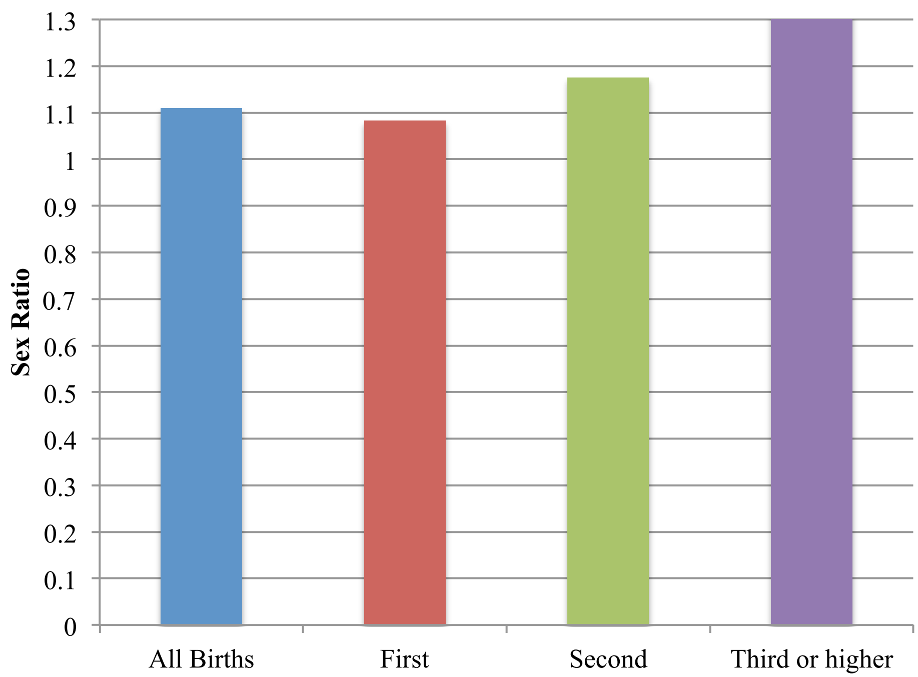

Figure 2: Average Smoking Rates By Trimester

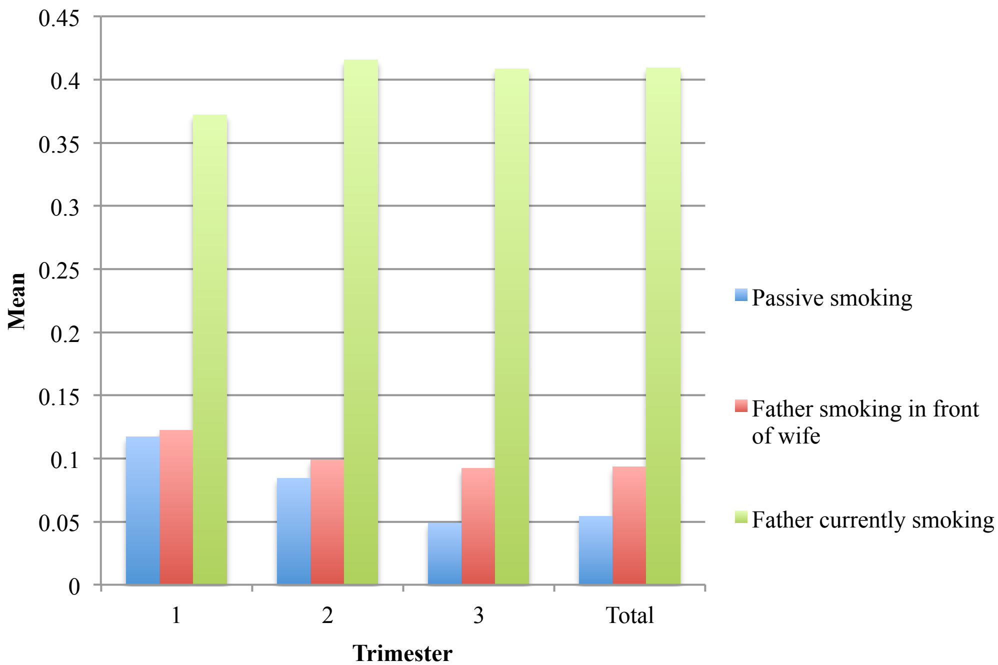

Table 1: Probability of having a male child and sex ratios by birth order

Birth Order	Probability of male infant (%)	Sex Ratio	Number of observations
All Births	52.60%	1.11	7778
First	52.00%	1.08	5975
Second	54.03%	1.18	1614
Third or higher	59.79%	1.49	189

Source: China Birth Cohort Study 2009-2012

Table 2: Smoking rates by trimester

Trimester	Passive smoking	Father smoking in front of wife	Father currently smoking
1	0.117	0.122	0.372
2	0.084	0.099	0.415
3	0.049	0.092	0.409
Total	0.054	0.093	0.409

Source: China Birth Cohort Study 2009-2012

Table 3a: Simple Difference-in-Differences for Multiple Observations of Prenatal Investment

	Girl			Boy			
	Ultrasound pre-20wk	**Ultrasound post-20 wk**	**DIFF (post-pre)**	**Ultrasound pre-20wk**	**Ultrasound post-20wk**	**DIFF (post-pre)**	**Diff-in-Diffs**
Sample Size	[269]	[9662]		[289]	[10663]		[20883]
Passive Smoking	0.078	0.054	-0.024*	0.142	0.052	-0.090***	-0.066***
SE			0.014			0.013	0.019
Smoke in front of wife	0.093	0.087	-0.006	0.163	0.098	-0.065***	-0.059**
SE			0.017			0.018	0.025
Father smoke	0.342	0.408	0.066**	0.429	0.412	-0.017	-0.084**
SE			0.030			0.029	0.042
Father drink	0.160	0.157	-0.003	0.194	0.159	-0.034	-0.031
SE			0.023			0.022	0.031
Nutrient Supplements	0.576	0.500	-0.077**	0.239	0.594	0.355***	0.432***
SE			0.031			0.029	0.043
Exercise	8.935	9.836	0.901*	8.915	9.770	0.855*	-0.046
SE			0.507			0.507	0.718
Diverse Diet	15.892	16.493	0.601	16.069	16.521	0.451	-0.150
SE			0.474			0.450	0.653

Source: China Birth Cohort Study 2009-2012
***p<0.1, **p<0.05, ***p<0.01**

Table 3b: Simple Difference-in-Differences for Multiple Observations of Prenatal Investment – Restricted to Sample with Ultrasounds Before and After Gestational Week 20

	Girl			Boy			
	Ultrasound pre-20wk	**Ultrasound post-20 wk**	**DIFF (post-pre)**	**Ultrasound pre-20wk**	**Ultrasound post-20 wk**	**DIFF (post-pre)**	**Diff-in-Diffs**
Sample Size	[269]	[682]		[289]	[722]		[1962]
Passive Smoking	0.078	0.066	-0.012	0.142	0.071	-0.071***	-0.059**
SE		0.018	0.014			0.020	0.027
Smoke in front of wife	0.093	0.075	-0.018	0.163	0.090	-0.073***	-0.055*
SE			0.020			0.022	0.029
Father smoke	0.342	0.339	-0.003	0.429	0.425	-0.004	-0.001
SE			0.034			0.049	0.042
Father drink	0.160	0.147	-0.013	0.194	0.176	-0.018	-0.005
SE			0.026			0.027	0.037
Nutrient Supplements	0.576	0.568	-0.009**	0.239	0.560	0.321***	0.330***
SE			0.036			0.033	0.049
Exercise	8.935	8.933	-0.002	8.915	8.680	-0.235	-0.233
SE			0.585			0.512	0.774
Diverse Diet	15.892	15.927	0.035	16.069	16.187	0.118	0.083
SE			0.540			0.514	0.745

***p<0.1, **p<0.05, ***p<0.01**

Table 4: Simple Differences in Gender for One-Time Observations of Prenatal Investment

	Girl	Boy	Diff(Boy-Girl)
Sample Size	[3590]	[3995]	
Mother weight gain	34.712	34.617	-0.096
SE			0.244
Sample Size	[3684]	[4091]	
Number of ultra	2.694	2.676	-0.018
SE			0.018

***p<0.1, **p<0.05, ***p<0.01**

Table 5: Difference-in-Differences for Multiple Observations of Prenatal Investment with Controls

	All	First Births	Higher-Order Births
Sample Size	[11448]	[9105]	[2343]
Passive Smoking	-0.058*	-0.048*	-0.078*
SE	0.028	0.023	0.036
Smoke in front of wife	-0.053	-0.038	-0.109
SE	0.032	0.032	0.083
Father smoke	-0.071	-0.051	-0.144***
SE	0.046	0.061	0.031
Father drink	-0.023*	-0.022**	-0.045
SE	0.010	0.008	0.053
Nutrient Supplements	0.439***	0.419***	0.535***
SE	0.022	0.014	0.109
Exercise	-0.270	0.637	-4.600
SE	0.195	0.484	2.859
Diverse Diet	0.033	-0.127	1.160
SE	0.498	0.443	1.753

Controls for year, month, parent's education, parent's age, parent's height, income, district
***p<0.1, **p<0.05, ***p<0.01**

Table 6: Gender Difference (Boy-Girl) for One-Time Observations of Prenatal Investment with Controls

	All	First Births	Higher-Order Births
Sample Size	[6660]	[5203]	[1457]
Mother weight gain	-0.134	-0.260	0.463***
SE	0.193	0.2635601	0.0768591
Sample Size	[6741]	[5249]	[1492]
Number of ultrasounds	-0.008	-0.003	-0.022
SE	0.012	0.019	0.046

Controls for year, month, parent's education, parent's age, parent's height, income, district
***p<0.1, **p<0.05, ***p<0.01**

Table 7: Fixed Effects Model for Multiple Observations of Prenatal Investment

	All	
	Girl	**Boy**
Total Sample Size	[690]	[728]
Sample Size	[690]	[728]
Passive Smoking	0.018***	-0.034
SE	0.003	0.018
Sample Size	[690]	[728]
Smoke in front of wife	0.015	-0.057***
SE	0.012	0.006
Sample Size	[690]	[728]
Nutrient Supplements	-0.020	0.280**
SE	0.034	0.090
Sample Size	[690]	[728]
Exercise	0.564*	-0.110
SE	0.251	0.169
Sample Size	[690]	[728]
Diverse Diet	0.120*	-0.053
SE	0.052	0.070

Note: 'Father Smoke' and 'Father Drink' omitted due to colinearity
Controls for year, month, parent's education, parent's age, parent's height, income, district
***p<0.1, **p<0.05, ***p<0.01**

Table 8: Difference-in-Differences of Multiple Observations of Prenatal Investment by Mother's Education and Family Income

	(1) Mother's Education		(2) Family monthly income (Yuans)					
	High School or below	Vocational School, College, or above	<1000	1000 - 2000	2000-3000	3000-4000	4000-5000	>5000
Sample Size	[3805]	[7643]	[549]	[1850]	[3489]	[2772]	[1480]	[1308]
Passive Smoking	-0.118**	-0.027	-0.206***	-0.060	-0.060**	-0.080	0.026	0.035
SE	0.041	0.035	0.040	0.081	0.031	0.054	0.046	0.032
Smoke in front of wife	-0.089	-0.030	-0.071	-0.079	-0.063***	-0.045	0.095**	-0.137
SE	0.054	0.016	0.159	0.045	0.014	0.070	0.025	0.173
Father smoke	-0.112	-0.051	0.002	-0.119	-0.022	-0.093	-0.134	-0.060
SE	0.074	0.038	0.144	0.072	0.083	0.093	0.135	0.153
Father drink	0.041	-0.062	0.034	-0.014	0.015	0.018	-0.236***	-0.050
SE	0.067	0.035	0.135	0.072	0.037	0.090	0.025	0.057
Nutrient Supplements	0.346***	0.486***	0.490*	0.413***	0.461***	0.449***	0.339**	0.435***
SE	0.011	0.022	0.221	0.064	0.051	0.069	0.098	0.087
Exercise	-2.176*	0.985*	-5.794***	-0.512	0.091	2.339*	-3.052	-1.159
SE	1.032	0.480	1.197	0.608	0.760	1.042	3.525	1.094
Diverse Diet	0.973	-0.466	-2.368	1.331*	0.769	0.494	-3.519*	0.571
SE	0.712	0.488	1.954	0.583	0.474	1.159	1.570	1.313

Controls for year, month, parent's education (mother's education omitted from (1)), parent's age, parent's height, income (income omitted from (2)), district
***p<0.1, **p<0.05, ***p<0.01**

Table 9: Placebo Tests with Controls

TEST 1		TEST 2	
Sample Size	[480]	**Sample Size**	[11448]
Passive Smoking	0.046	**Pre-pregnancy education**	0.021
SE	0.032	**SE**	0.019
Smoke in front of wife	0.056	**Food diversity 1 year before**	0.042
SE	0.029	**SE**	0.144
Father smoke	0.068	**Nutrient Supplements 1 year before**	-0.019
SE	0.041	**SE**	0.017
Father drink	0.030	**Exercise 1 year before**	-0.289*
SE	0.026	**SE**	0.136
Nutrient Supplements	-0.372***		
SE	0.034		
Exercise	0.013		
SE	0.419		
Diverse Diet	0.161		
SE	0.585		

Controls for year, month, parent's education, parent's age, parent's height, income, district
***p<0.1, **p<0.05, ***p<0.01**
TEST 1: Regression of health investments on gender before gestational week 20
TEST 2: Regression of health investments before pregnancy on gender

Table 10: Placebo Test with Fixed Effects
(Sample restricted to after gestational week 20)

	26 wk		30 wk	
	Girl	**Boy**	**Girl**	**Boy**
Sample Size	[2565]	[2683]	[2979]	[3203]
Passive Smoking	-0.017	-0.004	-0.008	0.009
SE	0.013	0.009	0.013	0.009
Smoke in front of wife	-0.014**	-0.013	-0.010	0.001
SE	0.005	0.007	0.005	0.002
Nutrient Supplements	0.006	0.049	0.020	0.079*
SE	0.023	0.032	0.021	0.038
Exercise	-0.262	-0.297 **	0.029	-0.132
SE	0.301	0.076	0.167	0.105
Diverse Diet	-0.139	0.010	0.081	-0.013
SE	0.093	0.058	0.047	0.036

Note: 'Father Smoke' and 'Father Drink' omitted due to colinearity
Controls for year, month, parent's education, parent's age, parent's height, income, district
***p<0.1, **p<0.05, ***p<0.01**

APPENDIX

Figure A1: Histogram of Gestational Week at Ultrasound Test Record

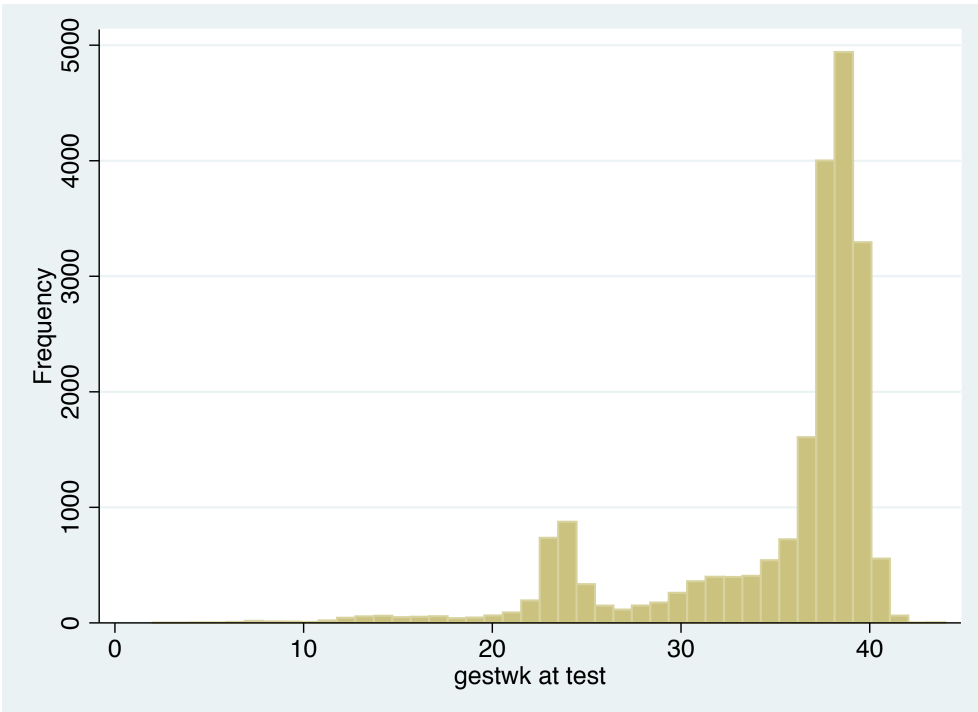

Table A1: Summary Statistics for Multiple Observations of Prenatal Investment

	Definition	All Births	Male	Female
# Observations	-	[20938]	[10952]	[9931]
Passive Smoking	Indicator for fetus exposure to environmental smoke during current trimester	0.054	0.054	0.0546
SE		0.226	0.226	0.227
Father smoking in front of wife	Indicator for whether father smokes in front of mother during current trimester	0.093	0.010	0.087
SE		0.291	0.299	0.282
Father currently smoking	Indicator for whether the father currently smokes	0.409	0.412	0.407
SE		0.492	0.492	0.491
Husband alcohol drinking	Indicator for whether the father currently drinks alcohol	0.158	0.412	0.157
SE		0.365	0.492	0.364
Nutrient Supplements	Indicator for whether mother has taken food supplements in the current trimester	0.545	0.584	0.502
SE		0.499	0.493	0.500
Exercise	Total number of exercise hours of mother in the current trimester	9.768	9.748	9.812
SE		8.358	8.501	8.194
Diverse Diet	Food diversity, measured by number of different foods eaten, of mother in the current trimester	16.502	16.509	16.477
SE		7.607	7.550	7.674

Pre-pregnancy education	Indicator for whether mother has pre-pregnancy education	0.531	0.534	0.528
SE		0.499	0.499	0.499
Food diversity 1 year before	Food diversity of mother 1 year before pregnancy	16.314	16.298	16.310
SE		7.455	7.4044	7.517
Nutrient Supplements 1 year before	Indicator for whether mother took food supplements 1 year before pregnancy	0.388	0.373	0.404
SE		0.487	0.484	0.490
Exercise 1 year before	Total number of exercise hours of mother per week one year before pregnancy	10.847	10.774	10.959
SE		9.688	9.693	9.692

Table A2: Summary Statistics for One-time Observations of Prenatal Investment

	Definition	All Births	Male	Female
# Observations		[7608]	[3995]	[3590]
Mother weight gain	Weight of mother pre-pregnancy subtracted from weight of mother before delivery, measured in kg	34.642	34.617	34.713
SE		10.616	10.575	10.653
# Observations		7799	4091	3684
Number of ultra	Total number of ultrasound records for a mother	2.684	2.676	2.694
SE		0.771	0.771	0.771

Table A3: Summary Statistics for Covariates

	Definition	All Births	Male	Female
# Observations		[20938]	[10952]	[9931]
Year	Year of record (2009-2012)	2011.021	2011.012	2011.025
SE		0.843	0.842	0.843
# Observations		[20938]	[10952]	[9931]
Month	Month of record (mo. 1 – 12)	6.458	6.469	6.442
SE		3.344	3.355	3.339
# Observations		[20678]	[10803]	[9820]
Mother's education	0 = none, 1 = primary school, 2 = junior high school, 3 = senior high school, 4 = vocational school, 5 = college, 6 = graduate school or above	4.945	4.913	4.983
SE		1.310	1.318	1.298
# Observations		[20585]	[10784]	[9746]
Father's education	0 = none, 1 = primary school, 2 = junior high school, 3 = senior high school, 4 = vocational school, 5 = college, 6 = graduate school or above	5.032	4.993	5.077
SE		1.282	1.302	1.256
# Observations		[20924]	[10947]	[9922]
Mother's age	Mother's age in years	29.035	29.0361	29.0345
SE		4.110	4.142	4.079
# Observations		[20924]	[10947]	[9922]
Mother's age squared	Square of mother's age	859.919	860.247	859.641
SE		247.731	249.392	246.168
# Observations		[20443]	[10715]	[9674]

Father's age	Father's age in years	31.206	31.18335	31.228
SE		4.751	4.806	4.686
# Observations		[20443]	[10715]	[9674]
Father's age squared	Square of father's age	996.404	995.499	997.169
SE		314.308	316.802	311.208
# Observations		[20682]	[10848]	[9779]
Mother's height	Mother's height in centimeters	162.171	162.158	162.190
SE		4.771	4.667	4.885
# Observations		[20585]	[10778]	[9752]
Father's height	Father's height in centimeters	173.922	173.925	173.912
SE		5.103	5.082	5.132
# Observations		[19164]	[10032]	[9081]
Income	Family income measured in yuans; 0 = <1000, 1 = 1000-2000, 2 = 2000-3000, 3= 3000-4000, 4 = 4000-5000, 5 = >5000	3.567	3.545	3.590
SE		1.349	1.356	1.342

Table A4: Likelihood of Receiving Ultrasound Pre-20wk and Socioeconomic Status

	Pre-20wk Ultrasound
# Observations	[6,764]
Mother's Education	
Primary School	0.0366
SE	0.0203
Junior High School	0.0308
SE	0.0219
Senior High School	0.0457**
SE	0.0148
Vocational School	0.0356
SE	0.019
College	0.0463*
SE	0.0182
Graduate School	0.0393**
SE	0.0137
Income (Yuans)	
1000-2000	-0.00984
SE	0.014
2000-3000	-0.000372
SE	0.0122
3000-4000	-0.00128
SE	0.0141
4000-5000	-0.0132
SE	0.00699
>50000	0.000541
SE	0.0088

Controls for year, month, father's education, parent's age, parent's height, district
***p<0.1, **p<0.05, ***p<0.01**