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Typically Unobserved Variables (TUVs) and Selection into Prenatal Inputs: Implications for Estimating Infant Health Production Functions

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ABSTRACT

We use survey data, augmented with data collected from respondents' medical records, to explore selection into prenatal inputs among a group of urban, mostly unmarried mothers. We explore the extent to which several theoretically important but typically unobserved variables (representing wantedness, tast for risky behavior, and maternal health endowment) are likely to bias the estimated effects of prenatal inputs (illicit drug use, cigarette smoking, and prenatal care) on infant health outcomes (birth weight, low birth weight, and abnormal conditions). We also explore the consequences of including other non-standard covariates and of using self-reported inputs versus measure of inputs that incorporate information from medical records. We find that although the typically unobserved variables have strong associations with both inputs and outcomes with high explanatory power, excluding them from infant health production functions does not substantially bias the estimated effects of prenatal inputs. The bias from using self-reported measure of the inputs is much more substantial. The results suggest promising new directions for research on the production of infant health.

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Introduction

Economists and researchers in a variety of other disciplines have long been interested in estimating the effects of prenatal inputs, such as prenatal care and cigarette smoking, on birth outcomes. Although correlations have been well established, it is extremely difficult to isolate causal effects because there may be unobserved "third factors" associated with both prenatal behaviors and birth outcomes. Instrumental variables techniques can, in theory, produce unbiased estimates. In practice, however, such methods are difficult to implement empirically and often produce implausible results.[1] A further complication is that a substantial amount of evidence indicates that prenatal substance use and prenatal care are misreported in birth certificates and surveys—the two key sources of data used to analyze infant health (Penrod and Lantz 2000; Reichman and Hade 2001; Kaestner, Joyce, and Wehbeh 1996; Noonan et al. 2005). At least for drug use, the misreporting is systematic, making it difficult to find appropriate instrumental variables (Kaestner, Joyce, and Wehbeh 1996). As a result, standard regression with well-measured and rich data remains an important component of a multi-pronged estimation strategy of identifying effects of prenatal inputs on infant health.

We use a uniquely rich dataset to undertake a comprehensive investigation of selection into illicit drug use, cigarette smoking, and prenatal care, among urban, unmarried mothers. We systematically explore whether including measures of the mother's wantedness of the pregnancy, taste for risky behaviors, and health endowment in infant health production functions affects estimates of effects of prenatal inputs. We also explore the role of paternal characteristics. The economic literature on infant health suggests that such characteristics are important, but most data sets used to analyze the effects of prenatal inputs on infant health outcomes do not include

[1] See Moffitt (2005) for an excellent discussion of the pros and cons of econometric methods to address unobserved heterogeneity.

measures of these inputs or contain poorly measured proxies. Additionally, given substantial evidence of misreporting of prenatal inputs by mothers, we use measures of prenatal inputs that take advantage of information documented in medical records. Finally, we move beyond birth weight by using a direct measure of infant health—abnormal infant conditions.

Specifically, we address the following five research questions: (1) Does a set of typically unobserved but theoretically important variables (representing wantedness, taste for risky behavior, and maternal health endowment) significantly explain the demand for prenatal inputs (illicit drug use, cigarette smoking, and prenatal care) and substantively improve the explanatory power of input demand equations? (2) Are the typically unobserved variables significantly associated with infant health outcomes (birth weight, low birth weight, and abnormal infant conditions)? (3) What are the effects of prenatal inputs on infant health outcomes in models with a rich set of covariates, including typically unobserved but theoretically important variables? (4) Do the typically unobserved variables have direct effects on infant health outcomes above and beyond their indirect effects through inputs? (5) How do the estimated effects of prenatal inputs on infant health outcomes change when the typically unobserved variables are included? How do they change when including other non-standard covariates and using self-reported measures of prenatal inputs?

Background

Since early work by Rosenzweig and Schultz (1983) and Corman, Joyce and Grossman (1987), many economists have used instrumental variables techniques to estimate the effects of prenatal inputs (frequently, prenatal care) on infant health outcomes (frequently, birth weight). In theory, these models account for the self-selection of mothers into prenatal care and risky prenatal behaviors. By examining the differences in the estimated effects of inputs on outcomes in one and two-stage models, inferences are made about the direction and extent of selection in input use. Although the results are mixed, most studies of the effects of prenatal care find evidence of adverse selection—that is, mothers with poor expected birth outcomes are more likely than those with favorable expected outcomes to seek care and to do so early.

It is difficult to compare estimates across studies of the effects of prenatal care on birth weight because they tend to use inconsistent measures of prenatal care, consider different birth weight outcomes (some examine birth weight in grams while others examine low birth weight), and focus on specific racial groups or other sub-populations. However, it appears that the estimates vary widely across studies.

The general lack of consistency across studies may reflect identification problems, and most researchers would agree that it is important to address the endogeneity issue in new ways. A recent study by Evans and Lien (2005) exploited a "natural experiment" as an alternative to estimating instrumental variables models with price/availability identifiers. That study found no overall significant effect of prenatal care on birth weight, although there was a positive effect among mothers who were early in their pregnancies. The finding of a small or no overall effect of prenatal care is consistent with results reported by Joyce (1999) and the literature on Medicaid expansions and birth outcomes that he cites. It is also consistent with findings from a recent

descriptive study with extremely rich data, including many typically unobserved but theoretically important variables (Reichman and Teitler 2005), and a recent review in the medical literature indicating that few features of prenatal care would be expected to increase birth weight at the aggregate level (Lu et al. 2003).

Fewer economic studies have examined selection into unhealthy prenatal behaviors, such as cigarette smoking and illicit drug use.[2] Rosenzweig and Schultz (1983), Lien and Evans (2005), and Noonan et al. (2005) all found no evidence of selection into prenatal cigarette smoking based on unobserved factors. Noonan et al. (2005) found a similar result for illicit drug use. Kaestner, Joyce and Wehbeh (1996) found that using self-reported drug use rather than actual drug use overstates the true effect of drugs on birth weight. They also found that when using instrumental variables estimation to address the reporting bias associated with self-reported drug use, estimates of the effect of drug use on birth weight were unbelievably large—almost quadruple the single-equation estimates.

Although there are fewer studies, estimates of the effects of substance use on birth weight are more consistent than they are for prenatal care. Lien and Evans (2005) and Noonan et al. (2005) found that cigarette smoking reduces birth weight due by about 180 and 225 grams, respectively. Noonan et al. (2005) and Kaestner, Joyce and Wehbeh (1996) found that accurately measured prenatal illicit drug use reduces birth weight by about 100 and 180 grams,

[2] The medical literature offers clear hypothesized mechanisms by which maternal cigarette smoking decreases birth weight. It also offers hypothesized mechanisms by which prenatal illicit drug use may reduce birth weight, but the associations do not appear to be as dose-response specific as that of smoking (Chomitz, Cheung, and Lieberman 1995). Prenatal alcohol use is generally considered a risky behavior and heavy use is associated with fetal alcohol syndrome, but the theoretical and empirical links between alcohol and birth weight are weak. For this reason, we do not include prenatal alcohol use in our analysis.

respectively.[3] Overall, using price/availability measures as identifiers, studies have not found strong evidence of unobserved heterogeneity in prenatal substance use, and estimates of the effects of smoking and drug use on birth weight are less variable than those of prenatal care. However, there are few existing studies and these findings must be replicated and further explored.

Another complication in estimating infant health production functions is that prenatal input use is often misreported. Penrod and Lantz (2000) found that mothers tend to report earlier care than what appears on birth certificates and that medical records indicate the greatest delay. They also found that women with adverse birth outcomes tend to over-report early prenatal care and that this reporting bias leads to underestimates of the effects of early prenatal care on birth weight. Reichman and Hade (2001) examined detailed data from physical examinations, medical records, and interviews and also found that early prenatal care is overreported in birth certificates. In addition, they found that prenatal cigarette smoking is underreported in birth certificates and that mothers' pre-pregnancy health conditions, which economic theory suggests may be important sources of selection into prenatal inputs, are substantially underreported in birth certificates. Finally, Kaestner, Joyce, and Wehbeh (1996) found substantial underreporting of illicit drug use when comparing results from drug tests at the time of the birth to data from birth certificates.

Finally, a limitation of previous research on infant health production that has received little attention is the exclusive focus on birth weight. Although birth weight is a widely used and well-measured index of subsequent morbidity, most low birth weight infants have no serious or long-term health conditions (Reichman 2005). As far as we know, no studies in the economics

[3] For the Kaestner, Joyce and Wehbeh (1999) study, we infer the effect based on their estimate of a 5.7 percent reduction in birth weight and a mean birth weight of 3,200 grams (a figure from our own data). The authors did not report the average birth weight in their sample.

literature have examined the production of infant health using direct measures of infant health, such as birth defects.

In sum, although numerous studies have estimated the effects of prenatal inputs (particularly prenatal care) on birth weight, it is clear that much more needs to be learned about selection into prenatal inputs and the effects of inputs on infant health. In the literature, selection has generally been attributed to three sets of factors—maternal health endowment, tastes, and wantedness—that are typically unobserved. Additionally, there is evidence of substantial underreporting of prenatal substance use and over-reporting of early prenatal care in both birth certificates and maternal interviews, and some evidence that the misreporting varies with birth outcomes. Systematic measurement error can lead to biased single equation estimates and make it difficult to find valid instrumental variables (Kaestner, Joyce, and Wehbeh 1996). Finally, previous economic research has focused narrowly on one index of infant health—birth weight—but has not explored direct measures of infant health.

Below we discuss what is known about the three theorized sources of selection and how they shape the production of infant health through the demand for prenatal inputs.[4]

Potential sources of selection

Wantedness

Grossman and Joyce (1990) modeled the decision to continue a pregnancy (rather than abort) as an endogenous determinant of birth outcomes using data on births and abortions in New York City. First they estimated the probability of giving birth, controlling for individual characteristics and availability of family planning and abortion services. They then computed λ, the inverse of the Mills ratio, for each woman who gave birth as a proxy for wantedness, and included λ in a birth weight production function. They found that the coefficient of λ was

[4] They also may have direct effects on infant health outcomes, which we discuss later.

positive and significant for black, but not white, women and inferred that black women with high levels of wantedness are more likely than those with low levels to have healthy babies.[5] The authors did not examine the mechanisms through which wantedness would translate to birth outcomes, but suggested that it likely operates through prenatal care or other inputs.

Joyce and Grossman (1990), using the same data, assessed the effects of λ (as a proxy for wantedness) on prenatal care use. They found that λ is negatively and significantly related to prenatal care delay among both blacks and Hispanics. That is, higher levels of wantedness lead to less delayed care. However, as the authors point out, "(e)arly prenatal care is but one form of healthy behavior. Pregnant women who initiate care promptly may eat more nutritiously, suffer less stress, engage in the appropriate exercise, and use fewer drugs and other potentially harmful substances than women who begin late care" (Grossman and Joyce 1990, p. 985).

The results of Joyce and Grossman (1990) are consistent with findings from numerous descriptive studies (Weller et al. 1987; Marsiglio and Mott 1988; Altfeld et al. 1997; Faden, Hanna, and Graubard 1997; Kost, Landry, and Darroch 1998; Pagnini and Reichman 2000; Coleman, Reardon, and Cougle 2005), most of which used direct retrospective assessments of wantedness or intention. Collectively, they indicate that unwanted or unintended pregnancy is negatively associated with prenatal care use and positively associated with unhealthy prenatal behaviors. Another study by Joyce, Kaestner, and Korenman (2002) found that the retrospective assessment of pregnancy intention does not produce misleading estimates in either the extent or estimated consequences (e.g., on birth weight) of unintended fertility.

[5] λ is inversely related to the probability of giving birth (versus aborting). Joyce and Grossman (1990) interpreted λ as a measure of wantedness, as women with a high λ had a low likelihood of continuing the pregnancy but decided to do so. They inferred that women with high λs had strong unmeasured desire for their babies.

Taste for risky behaviors and maternal health endowments

Recent studies (Bell and Zimmerman 2003; Clarke et al. 1999; Echevarria and Frisbie 2001; Pagnini and Reichman 2000) have found that prenatal cigarette smoking, alcohol consumption, and illicit drug use are associated with inadequate, late, or no prenatal care. These findings are consistent with, but do not prove, a hypothesis that a taste for risky prenatal behavior leads to poor prenatal care use. Ogunyemi and Hernandez-Loera (2004) found that mothers who use cocaine during pregnancy are more likely than those who do not use cocaine to have sexually transmitted diseases (STDs), previous medical problems, obstetric complications, and previous preterm deliveries. These findings suggest that having an STD during pregnancy may serve as a proxy for taste for risky behavior.[6]

Cardiac disease, hypertension, chronic diabetes, and other health conditions are associated with an increased likelihood of intrauterine growth retardation (Bernabe et al. 2004) and therefore may affect the mother's expected birth outcome and her use of prenatal inputs. Two recent studies examined the effects of maternal mental health on prenatal behavior and infant health outcomes. Warner (2003) and Conway and Kennedy (2004) found that maternal depression reduces the likelihood of adequate prenatal care among black, but not white, women. Conway and Kennedy posited that not only may depression affect birth weight through prenatal behaviors, but it may also have direct effects on birth weight through the mother's biochemistry. They found evidence of direct negative direct effects for whites, but not blacks, holding prenatal care use constant. Thus, they found some evidence of both direct and indirect effects of maternal depression on birth weight.

[6] STDs also may affect birth outcomes directly (see Goldenberg et al. 1997 for a discussion of hypothesized medical pathways).

Our contribution

Overall, past research indicates that: (1) despite a substantial amount of research, estimates of the effects of prenatal care on birth weight vary widely; (2) theory and past empirical research suggest that wantedness, tastes, and maternal health endowment may underlie some of the selection into prenatal inputs; (3) little is known about the extent of and sources of selection into prenatal substance use, particularly illicit drug use; (4) there is evidence of misreporting of prenatal inputs—in socially desirable directions—in both birth certificates and surveys; and (5) as far as we know, no economic studies of infant health production have used direct measures of infant health. The literature is fragmented and no single study has accounted for theorized sources of selection or examined multiple well-measured inputs and outcomes, due to data limitations. In this study, we use uniquely rich data to explore the extent to which measures or proxies for wantedness, taste for risky behavior, and maternal health endowment bias the estimated effects of three different prenatal inputs on birth weight as well as a direct measure of infant health.

Data

We use data from a recent national birth cohort survey that have been linked to medical records of mother respondents and their babies and to neighborhood characteristics at the census tract level. The Fragile Families and Child Wellbeing (FFCWB) survey follows a cohort of parents and their newborn children in 20 large U.S. cities (in 15 states). The study was designed to provide information about the conditions and capabilities of new (mostly unwed) parents; the nature, determinants, and trajectories of their relationships; and the long-term consequences for parents and children of welfare reform and other policies. The survey data are rich in

sociodemographic characteristics of both mothers and fathers, and include information on parents' relationships and living arrangements.

The FFCWB study randomly sampled births in 75 hospitals between 1998 and 2000. By design, approximately three quarters of the interviewed mothers were unmarried. Face-to-face interviews were conducted with 4898 mothers while they were still in the hospital after giving birth.[7] Additional data have been collected from the hospital medical records (from the birth) for a sub-sample of 2994 births in 17 cities (in 13 states). The medical record data contain information on prenatal substance use from laboratory tests of the mother or baby and in notes by physicians or social workers; information on the timing of prenatal care initiation; and detailed measures of the mother's health endowment (more detail is given below, under "Measures"). Measures of census tract-level poverty were linked to the data using the mothers' baseline addresses. Follow-up interviews were conducted with mothers when the child was one and three years old. We use data on the 2,638 non-multiple births that have complete information on all main analysis variables from the baseline survey, medical records, and address files.

Measures

Sample means for the three prenatal inputs—illicit drug use, cigarette smoking, and prenatal care—are presented in the top panel of Table 1 and those for the other analysis measures are presented in the other panels. The measures are defined and described below.

Unhealthy Inputs: Illicit Drugs and Cigarettes

Arendt et al. (1999) found that using postpartum interviews combined with medical records was the best way to ascertain illicit substance use during pregnancy. Although the

[7] Additional background on the research design of the FFCWB study is available in Reichman et al. (2001).

FFCWB baseline interview was far less detailed than that used by Arendt et al., we adopt the strategy of combining responses to a postpartum survey with a review of the mothers' and babies' medical records for each of the unhealthy inputs. During the mother's interview in the hospital after giving birth, she was asked whether she had used any illicit drugs and whether she had smoked cigarettes during her pregnancy. This information was combined with detailed information from medical records, described below, to create measures of prenatal substance use.

Prenatal illicit drug use

The medical records contain information about the mother's drug use during pregnancy from laboratory tests of the mother or baby and in notes by physicians, nurses, or social workers. Forty three percent of the 2,638 mothers in our sample had results from urine toxin screens in their charts; of these 13.5 percent tested positive for cocaine, heroin, marijuana, other drugs (including amphetamines, methadone and barbiturates/benziodiazepines) or unspecified drugs, or a combination of drugs. More cases of prenatal drug use were picked up from notes in various places in the mothers' and babies' charts. Overall, 9.9 percent of the mothers in our sample had some indication of prenatal drug use recorded in their own or their baby's chart.

Our measure of prenatal drug use is whether there was any indication of prenatal drug use from the interview *or* medical records (10.9%).[8] This figure is in the range presented in a review of sixteen studies by Howell et al. (1999). It is higher than the rates found in a recent survey that asked individuals whether they were pregnant, and if they were, whether they had used any illicit drugs in the past month (3.3%) and whether they had used any hard drugs in the past month

[8] We think it unlikely that mothers who had not used illicit drugs during pregnancy would report in their postpartum interviews that they had done so.

(1.1%) (Substance Abuse and Mental Health Services Administration [SAMHSA], 2000).[9] Less than 50 percent of drug-using pregnant women in our sample admitted having used drugs during pregnancy (see Table 1).

Prenatal cigarette smoking

Our measure of prenatal cigarette smoking, whether the mother smoked at all during pregnancy, also combines maternal postpartum reports with information in the medical records. The reports of smoking from the two sources differ much less than those of illicit drug use. Almost one quarter (23%) of the mothers smoked cigarettes at all during pregnancy according to their medical records or self-reports, while 19 percent reported that they had smoked at all. These figures are comparable to national estimates, which indicate that 19 percent of pregnant women report smoking in the past month.[10]

Healthy Input: Prenatal care

Based on the medical records, 48 percent of the mothers in our sample initiated prenatal care in the first trimester, 38 percent began care later than the first trimester, and 14 percent had missing information on when care began. According to mothers' baseline interviews, 77 percent of the mothers received prenatal care in the first trimester. We used the medical record information on the timing of prenatal care initiation when it was available to construct a measure of whether the mother received first trimester care (versus later than that or not at all). For mothers with missing information, we used self-reports. According to this measure, 57 percent of the mothers received first trimester prenatal care.[11]

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[9] The SAMHSA data are from the National Household Survey on Drug Abuse for 2000 and, when weighted, are representative of the U.S. population age 12 and over. The specific computation was for pregnant women age 15 to 44 within the overall sample. http://www.oas.samhsa.gov/nhsda/2kdetailedtabs/Vol_1_Part_4/sect6v1.htm#6.23b .

[10] Source: SAMHSA, National Household Survey on Drug Abuse, 2000. http://www.oas.samhsa.gov/nhsda/2kdetailedtabs/Vol_1_Part_4/sect6v1.htm#6.26b.

[11] We conducted supplementary analyses that excluded observations with missing medical records information on prenatal care. The results were insensitive to this alternative specification (results not shown).

Typically Unobserved Variables (TUVs)

We include a number of measures, most of which are from the medical records, that reflect theoretically important but typically unobserved sources of selection into prenatal inputs. Below we describe these measures, which we refer to as TUVs, and later (under "Analytical and Empirical Implementation") we discuss how each fits into the economic model of infant health production.

During the postpartum interview, the mother was asked whether she had considered having an abortion rather than carrying the pregnancy to term. In our sample, almost 30 percent of the mothers reported that they considered having an abortion when they found out that they were pregnant (we code these pregnancies as unwanted).

We use information from the prenatal records on STDs and other infections that are often transmitted sexually. One quarter (26%) of the mothers in our sample had at least one of the following infections, which are either always or often transmitted sexually, during pregnancy: pelvic inflammatory disease, syphilis, chlamydia, genital herpes, gonorrhea, human papilloma virus, hepatitis B, hepatitis C, or human immunodeficiency virus.

We include information from the medical records on a variety of health conditions in the mother's medical history (prior to the pregnancy). These measures include lung disease (acute or chronic lung disease or asthma), other pre-existing health conditions (cardiac disease, chronic diabetes, hypertension, or liver disease), under weight (Body Mass Index less than 18.5), and morbid obesity (Body Mass Index greater than or equal to 39).

We also include a measure of the mother's mental health endowment. The mother was coded as having a pre-existing mental illness if there was any documentation of a diagnosed

DSM-IV mental disorder (e.g., depression, anxiety, bipolar disorder, schizophrenia, anorexia, suicidality, and mental retardation) in her chart.[12]

Other Characteristics

We include a basic set of covariates that are typically available in existing data sets—maternal age (in years), education (which we code as high school graduate, some college but not a graduate, or college graduate—compared to less than high school), race/ethnicity (non-Hispanic black, Hispanic, or other non-white non-Hispanic—compared to non Hispanic white), nativity (whether the mother was foreign-born), marital status (whether the mother was married to the baby's father at the time of the birth), and parity (whether it was the mother's first birth).

One of the advantages of the FFCWB survey data is that they include a rich set of characteristics of the mother, father, and the parents' relationship status that may be related to both input use and infant health. For example, recent studies have found paternal factors to be independent predictors of prenatal input use (Teitler 2001; Sangi-Haghpeykar et al. 2005; Huang and Reid, forthcoming) and infant health (Reichman and Teitler, forthcoming). From the survey, we include insurance information (whether the birth was covered by Medicaid or other government program—henceforth referred to as "Medicaid"), whether the mother lived with both of her parents at age 15, whether she attends religious services several times per month, whether she knew the father at least one year prior to conception, the father's age (expressed as the number of years the father's age exceeded the mother's age), whether the father was a different race/ethnicity than the mother, and whether the father had fewer years of education than the mother. We also include the number of previous pregnancies (whether they resulted in live births or not, and including both spontaneous and induced abortions), which was obtained from the mother's medical record, and the percentage of households in the mother's census tract with

[12] Substance abuse disorders were not included in this measure.

income under the poverty line.[13] We refer to this set of measures as "other non-standard covariates."

The sample is predominately minority and poor (Table 1). Half (48%) of the sample is black and one third (30%) is Hispanic. Over one-third of the mothers did not complete high school. Two thirds were on Medicaid at the time of the birth.

Infant Health Outcomes

We estimate infant health production functions for birth weight (in grams) and low birth weight (< 2500 grams). Birth weight was obtained from the medical records. We also estimate production functions for a direct measure of infant health—whether the infant had a serious abnormal condition (i.e., one that is associated with both immediate and longer-term morbidity). The coding was conducted by an outside pediatric consultant who systematically reviewed the medical record data on infant conditions, as well as data from the one-year interviews on physical disabilities of the child (identifying serious conditions that were likely present at birth). For this analysis, the coder was instructed to exclude abnormalities for which there either is no connection to prenatal behavior or only a very weak connection. The excluded conditions (e.g., Down Syndrome, congenital heart malformations) are for the most part random, given that the pregnancy resulted in a live birth. Eleven percent of the infants in our sample were low birth weight and 12 percent had serious abnormal conditions as we have defined them (Table 1).

[13] In this sample, there is an average of 1.5 births per census tract, with 69 percent of the 1174 tracts containing only one birth.

Analytical Framework and Empirical Implementation

Following Corman, Joyce, and Grossman (1987) and the theoretical literature on which they build, we assume the parents' utility is a function of consumption goods (C), infant health (H), and tastes as follows:[14]

(1) $U=U(C, H; tastes)$

Infant health is a function of prenatal inputs, as well as the health endowment of the mother, as described in the infant health production function that follows:

(2) $H = f(input_1, input_2, \ldots input_n, health\ endowment)$

The demand for each input can be modeled as follows:

(3) $Input_i = g_i$ *(price/availability of* $input_i$*, prices/availability of substitute and complementary inputs, income, health endowment, tastes)*

The breadth and scope of our analyses preclude estimating a structural system with three endogenous inputs.[15] Our strategy is to use well-measured and rich data (including measures of theoretically important sources of heterogeneity), systematically examining patterns across model specifications, and importantly, assessing the plausibility of our results in the light of theory and past research. Of course, it is possible that despite our best efforts to correctly specify models to address our research questions, some endogeneity remains. However, in our analyses, we are less concerned with obtaining accurate point estimates than examining overall patterns of results.

Based on the general model above, we specify equations that reflect our research questions and that incorporate our specific TUVs. We consider unwantedness as a taste or

[14] We assume that the parents maximize one (joint) utility function. Others, including Rosenzweig and Schultz (1983), assumed an individual (maternal) utility function.

[15] Arguably, the only determinants of infant health that are exogenous are race/ethnicity and nativity. Yet, economic studies of health production often assume (for practical purposes) that education, parity, maternal age, and other factors are exogenous.

preference. In our sample, whether a mother considered an abortion represents her feeling about the pregnancy, given that it resulted in a live birth. This taste or preference should affect infant health exclusively through the inputs (i.e., unwantedness should not have a direct effect on infant health). The STD measure serves two roles: First, it may reflect a taste for risky behavior, which could affect outcomes through input demand. Second, it measures a health condition that could affect input demand and also have direct effects on infant health. The other five TUVs (pre-existing lung disease, other pre-existing physical health condition, pre-existing mental illness, pre-pregnancy underweight, and pre-pregnancy morbidly obese) all reflect health endowment and therefore may have both indirect (through inputs) and direct effects on infant health.

To address our first research question (whether TUVs explain the demand for inputs and increase explanatory power), we estimate separate demand equations for each input as follows:

(3a) $Input_i = g_i$ *(city fixed effects, parents' characteristics, TUVs)*

We estimate the demand for each of the following prenatal inputs as a function of a set of covariates that reflect income, health endowment, and tastes: (1) any illicit drug use, (2) any cigarette smoking, and (3) first trimester prenatal care. Because the inputs are dichotomous, we estimate probit models. We include city fixed effects to control for local input prices, availability, and policies. Many of our covariates (e.g., education and census tract-level poverty) are proxies for income. The TUVs are measures of health endowment and tastes, as discussed above. We assess the magnitude and significance of the TUVs as well as their contribution to the explanatory power of the input demand equations.

To address our second research question (whether TUVs are significantly associated with infant health), we estimate reduced-form production functions for each health outcome (birth

weight, low birth weight, and abnormal conditions) that include the same right-hand-side variables as Equation 3a:

(2a) Health Outcome = f (city fixed effects, parents' characteristics, TUVs)

We address our third research question (the effects of prenatal inputs on infant health) by estimating quasi-structural production functions that include the prenatal inputs in addition to the other right-hand-side variables:

(2b) Health Outcome = f (prenatal inputs, city fixed effects, parents' characteristics, TUVs)

To the extent that STDs represent a taste for risky behavior, that measure would not directly enter the health production function. Similarly, unwantedness represents a taste and would not directly enter the health production. However, tastes are related to input use (Equation 3). If all relevant inputs are not included in the infant health production function, then excluding tastes could lead to biased estimates of the effects of included prenatal inputs. Therefore, we include variables reflecting tastes (STDs and unwantedness) in Equation 2b in addition to the TUVs that measure health endowment.

We use the same set of quasi-structural production functions to address our fourth research question (whether TUVs are significantly associated with infant health, holding inputs constant). We assess both the statistical significance of the individual TUVs and their overall contribution to explanatory power.

To address our fifth research question (how much of a difference the TUVs, non-standard covariates, and well-measured inputs make when estimating the effects of prenatal inputs on infant health), we re-estimate Equation 2b: (1) excluding the TUVS; (2) excluding the TUVs and using only typically available covariates; and (3) excluding the TUVS, using only typically available covariates, and using self-reported measures of inputs. The last specification

corresponds to a standard model that can be estimated with birth certificate data. We compare the estimated effects of inputs across models.

Results

Question 1: Does a set of typically unobserved but theoretically important variables (representing wantedness, taste for risky behavior, and maternal health endowment) significantly explain the demand for prenatal inputs (prenatal care, illicit drug use, and cigarette smoking) and substantively improve the explanatory power of input demand equations?

Table 2 presents probit results for illicit drugs, cigarettes, and first trimester care, respectively. In each cell, the first figure represents the probit coefficient, the figure in parentheses is the standard error of the probit coefficient, and the figure in brackets represents the marginal effect. We also report the predicted probability, pseudo R^2, and sample size for each model, as well as the pseudo R^2 from corresponding models that exclude the TUVs.

For illicit drug use, the mother's education, marital status, nativity, religious attendance, and the father's characteristics all have significant associations in the expected directions. In addition, we find that our measure of unwantedness has a strong positive association. Finally, having an STD has a strong, positive association with illicit drug use during pregnancy, as does having a pre-existing diagnosed mental illness.[16]

For prenatal cigarette smoking, parental characteristics are associated with smoking in the expected directions. The wantedness of the pregnancy, proxied by whether the mother considered having an abortion, has a large and highly significant association with prenatal cigarette smoking: Women who considered having an abortion were 8 percentage points more likely than those who did not consider having an abortion to smoke cigarettes during pregnancy. Having been diagnosed with an STD during pregnancy increases the likelihood that the mother

[16] The magnitude of the coefficient of mental illness may seem high, but it is consistent with a "self-medication hypothesis" discussed by numerous researchers and recently tested by Harris and Edlund (2005).

smoked cigarettes by 3 percentage points. Additionally, mothers with diagnosed mental illnesses were 17 percentage points more likely than those without such diagnoses to smoke cigarettes during pregnancy. To summarize thus far, Table 2 indicates that unwantedness, pre-existing mental illness, and STDs are associated with significantly higher rates of substance use among pregnant women.

Mothers who considered abortion were 14 percentage points (about 25%) less likely to receive first trimester prenatal care than those who did not consider abortion. STDs and mental illness, which were strong predictors of smoking and drug use, are not significant predictors of first trimester care. However, we find strong evidence for adverse selection into early prenatal care based on the mother's physical health endowment. Mothers with pre-existing conditions other than lung disease were 8 percentage points more likely than those without conditions to get first trimester care.

At the bottom of Table 2, we can see that the set of TUVs increases the pseudo R^2s for drugs, smoking, and first trimester care by 50, 12, and 29 percent, respectively. Overall, the results in Table 2 indicate that: (1) TUVs are strong predictors of prenatal inputs in the expected directions, but the associations vary by TUV and input. (2) Unwantedness, as characterized by having considered an abortion, is a strong predictor of both prenatal substance use and late or no prenatal care. (3) Pre-existing diagnosed mental illness is a strong predictor of prenatal smoking and drug use, as are STDs. (4) The mother having a pre-existing physical health problem is an important predictor of first trimester prenatal care.

Question 2: Are TUVs significantly associated with infant health outcomes (birth weight, low birth weight, and abnormal infant conditions)?

Table 3 shows reduced-form estimates of the effects of each of the TUVs on birth weight, low birth weight, and abnormal infant conditions. These effects represent the combined indirect effect of the TUV via input use plus the direct effect (if any) on the health outcome. All models include the full set of covariates from Table 2. For birth weight, we estimate an Ordinary Least Squares model and present coefficients with standard errors in parentheses. For low birth weight and abnormal conditions, we estimate probit models and present marginal effects calculated at mean values with standard errors of the marginal effects in parentheses. We find that the significance (and sometimes the sign) of the different TUVs varies by outcome.

Although Table 2 indicates that our measure of unwantedness is positively related to prenatal substance use and negatively associated with first trimester care, Table 3 indicates that it does not have a significant adverse association with infant health. Pre-pregnancy morbid obesity is not significantly associated with infant health outcomes, but pre-pregnancy underweight reduces birth weight. Pre-existing lung disease and other health conditions increase the likelihood of low birth weight. History of mental illness is strongly associated with both birth weight and low birth weight, in the expected directions, and STDs are a significant risk factor for abnormal conditions.

Question 3: What are the effects of prenatal inputs on infant health outcomes in models with a rich set of covariates, including TUVs?

Results from quasi-structural infant health production functions are presented in Table 4. These models include the three inputs, the TUVs and the full set of covariates. We find that prenatal illicit drug use reduces birth weight by 120 grams and that it increases the likelihood of an abnormal infant condition by six percentage points. The estimates for prenatal cigarette

smoking are very similar to those from previous literature discussed earlier. We find that smoking decreases birth weight by 188 grams and increases the likelihood of low birth weight by 6 percentage points, but that it is unrelated to abnormal infant conditions. Consistent with findings in recent studies by Lien and Evans (2005) first trimester care is unrelated birth weight and low birth weight.[17] It is also unrelated to abnormal infant conditions.

Due to the possibility of collinearity between prenatal smoking and illegal drug use (two-thirds of the drug users smoked cigarettes), we ran a set of quasi-structural production functions with prenatal care plus the following three indicators of prenatal substance use: *smoking but no drugs* (N = 410), *drugs but no smoking* (N = 99), and *both smoking and drugs* (N = 193), all compared to *no smoking or drugs* (N = 1,936). The pattern of results (not shown in tables) was very similar to that in Table 4. For birth weight and low birth weight, the effects of *drugs but no smoking* were insignificant; the effects of *smoking but no drugs* were slightly smaller in magnitude than those in Table 4, but still large in magnitude and highly significant; and the effects of engaging in both behaviors exceeded the sum of the coefficients for smoking and drugs in Table 4. For abnormal conditions, the effect of *drugs but no smoking* and the effect of *smoking but no drugs* were both insignificant. However, the effect of *both smoking and drugs* had a similar effect to the effect of drugs from Table 4. Overall, these supplementary results indicate that multicollinearity does not seem to be a major problem in our analyses.

[17] Supplemental results indicate that prenatal care did not improve birth outcomes by altering the quantity or duration of substance use. We tested this by estimating alternative models that included prenatal care but not substance use. First trimester care became significant at the 10% level for birth weight, but was still associated with a small (39 gram) increase. Additionally, first trimester care had no association with low birth weight or abnormal infant conditions (results not shown).

Question 4: Do the TUVs have direct effects on infant health outcomes above and beyond the indirect effects through inputs?

From Table 4, we find compelling evidence of direct effects of TUVs on infant health outcomes. That is, not only are TUVs strongly related to prenatal input use, but some are also related to infant health outcomes when holding inputs constant. The strength of the association depends on the specific TUV and outcome. Even when controlling for the three inputs, we find that: (1) underweight (possibly representing nutritional inadequacy) is a strong and significant predictor of birth weight but not low birth weight or abnormal infant conditions; (2) maternal physical and mental health endowments are strongly related to low birth weight; and (3) STDs are strongly related to abnormal infant conditions. With only one exception, all of these associations are in the expected directions and consistent with theory.[18]

Question 5: How do the effects of prenatal inputs on infant health outcomes change when the typically unobserved but theoretically important variables are included? How do they change when including other non-standard covariates and using self-reported measures of prenatal inputs?

In the final step of our analysis, we present estimates from a set of quasi-structural production functions with alternate specifications. These allow us to examine the extent to which the TUVs and other non-standard covariates modify the coefficients of the prenatal inputs. They also allow us to compare our results from Table 4 with those from a "typical" model with self-reported inputs and a standard set of covariates. These results are presented in Table 5.

The first figure in each cell of Table 5 is identical to the corresponding figure in Table 4. The second estimate is from a model that excludes the TUVs. The third estimate is from a basic model that includes only variables that are typically available in birth certificates: maternal age, education, race/ethnicity, nativity, first birth, previous pregnancies, marital status, and city fixed

[18] The small positive (marginally significant) association between considered abortion and birth weight deserves further investigation in future research.

effects. The last estimate in each cell is from a model with the same set of covariates as the third figure but using the self-reported inputs instead of the measures that combine medical records and interview data. Overall, from top to bottom, the model becomes much less specified and the inputs become less accurately measured.

Several findings stand out from Table 5: (1) Including the TUVs (A versus B) increases the explanatory power of the health production functions for low birth weight and abnormal infant conditions. (2) In general, including the TUVs changes the estimated effects of substance use very little. Using the combined measures of inputs (instead of self-reports) and including the non-standard covariates result in smaller estimated effects of inputs on outcomes than when using self-reported inputs and a limited set of covariates. (3) Prenatal illicit drug use is significantly associated with abnormal infant conditions, regardless of specification, although the magnitude is lower in the fuller models. (4) We find no effect of first trimester prenatal care on birth weight, low birth weight, or abnormal infant conditions, except when the self-reported measure of prenatal care is used (D). That estimate suggests large effects on birth weight and low birth weight.

Conclusion

We examined the effects of typically unobserved but theoretically important variables, which we call TUVs, on prenatal input demand and infant health production functions. The TUVs included measures of maternal health endowment, taste for risky behavior, and wantedness of the pregnancy, all of which economists have theorized are potential sources of endogeneity of prenatal inputs. Using a uniquely rich dataset, we were able to measure these factors directly (albeit imperfectly). We found that the TUVs are strongly associated with both

prenatal inputs and infant health outcomes, but that the associations vary by TUV, input, and outcome. Additionally, we found that adding TUVs to input demand and infant health production functions adds substantially to the explained variation in those equations.

Despite the strong associations of the TUVs with both inputs and outcomes, however, excluding them from health production functions does not substantially bias the estimated effects of prenatal inputs. The bias from using self-reported measures of the inputs is actually much more substantial than that resulting from excluding the TUVs. That is, reporting bias appears to be more consequential than omitted variables bias for estimating the effects of prenatal inputs on infant health outcomes. This result underscores the importance of collecting accurate measures of prenatal behaviors.

The majority of economic studies of the production of infant health focus on the effect of prenatal care on birth weight. Consistent with recent studies, we found that first trimester prenatal care appears to have little to no effects on birth weight, low birth weight, or abnormal infant conditions. This finding was robust to the exclusion of the measures of substance use.

When including all three inputs, we found that cigarette smoking and illicit drug use are stronger and more robust determinants of birth weight than first trimester prenatal care. We also found that prenatal illicit drug use, but not smoking or prenatal care, is associated with a direct measure of infant health—abnormal infant conditions. Thus, although smoking clearly affects birth weight, as has been shown in past research, it is unrelated to the infant's health status at birth. This pattern of results is not inconsistent, because birth weight is only a marker for risk of poor infant health. That said, the results should not be interpreted to mean that smoking is not harmful to infants' health. The birth weight effects of smoking may lead to cognitive deficiencies. Additionally, mothers who smoke cigarettes during pregnancy are likely to smoke

postnatally, exposing the child to second-hand smoke, which can have adverse health consequences. Similarly, the finding of no effects of prenatal care should not be interpreted as meaning that first trimester prenatal care has no beneficial effects on child health, as it is possible that prenatal care enhances child health by increasing the use of pediatric care.

The key take-home messages from this study are as follows: When well-measured inputs are used, infant health production functions with a standard set of covariates lead to similar estimates of the effects of prenatal inputs as those that include non-standard covariates and TUVs. Self-reported prenatal inputs lead to biased estimates in infant health production functions that cannot be easily overcome by using instrumental variables techniques. More attention should be paid to prenatal illicit drug use and direct measures of infant health when analyzing the productivity of prenatal inputs.

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Table 1: Characteristics of Sample

	Mean (N = 2638)	Standard Deviation
Prenatal Inputs		
Based on Medical Records and Maternal Self-Reports		
Used Illicit Drugs	.11	
Smoked Cigarettes	.23	
Received First Trimester Prenatal Care	.57	
Based on Maternal Self-Reports		
Used Illicit Drugs	.06	
Smoked Cigarettes	.19	
Received First Trimester Prenatal Care	.77	
Typically Unobserved Variables (TUVs)		
Considered Abortion	.30	
Pre-Existing Lung Disease	.13	
Other Pre-Existing Health Condition	.08	
History of Mental Illness	.10	
STD During Pregnancy	.26	
Pre-Pregnancy Underweight	.04	
Pre-Pregnancy Morbidly Obese	.02	
Mother Characteristics		
Mother's Age (years)	24.94	5.92
Mother's Age Squared	657.00	325.51
Less Than High School*	.36	
High School Graduate	.31	
Some College (but not graduate)	.23	
College Graduate	.09	
Medicaid Birth	.67	
Non-Hispanic White*	.18	
Non-Hispanic Black	.48	
Hispanic	.30	
Other Race/Ethnicity	.04	
Immigrant	.16	
First Birth	.37	
Number of Previous Pregnancies	.76	.43
Lived With Both Parents At Age 15	.42	
Attends Religious Services Several Times Per Month	.38	
% Under Poverty in Census Tract	.19	.13
Father Characteristics		
Less Educated Than Mother	.26	
Different Race/Ethnicity Than Mother	.15	
Years Older Than Mother	2.70	5.22

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Table 1 (continued): Sample Characteristics

Parents' Relationship		
Knew Each Other at Least 12 Months at Time of Conception	.84	
Married at Time of Birth	.23	
Infant Health Outcomes		
Birth Weight (grams)	3221	615
Low Birth Weight (< 2500 grams)	.11	
Abnormal Infant Health Condition	.12	

**Omitted Category in Regression Models*

Table 2: Demand for Prenatal Inputs

	Illicit Drug Use	Cigarette Smoking	First Trimester Prenatal Care
		Coefficient (Standard Error) [Marginal Effect]	
Mother's Age	.04 (.06) [.00]	.07* (.04) [.02]	.14*** (.04) [.06]
Mother's Age Squared	-.00 (.00) [-.00]	-.00 (.00) [-.00]	-.00*** (.00) [-.00]
High School Graduate	-.35*** (.08) [-.04]	-.32*** (.09) [-.08]	.18** (.06) [.07]
Some College	-.58*** (.11) [-.05]	-61*** (.09) [-.13]	.11 (.08) [.04]
College Graduate	-1.16*** (.25) [-.07]	-1.18*** (.08) [-.18]	.33*** (.12) [.12]
Medicaid Birth	.06 (.11) [.01]	.14** (.07) [.04]	-.16*** (.06) [-.06]
Non-Hispanic Black	.22 (.15) [.03]	-.62*** (.12) [-.16]	-.05 (.08) [-.02]
Hispanic	-.16 (.16) [-.02]	-.83*** (.12) [-.18]	-.03 (.09) [-.01]
Other Non-White Non-Hispanic	-.07 (.24) [-.01]	-.29 (.29) [-.07]	-.40*** (.14) [-.16]
Immigrant	-.85*** (.22) [-.06]	-.79*** (.13) [-.16]	-.05 (.09) [-.02]
Lived With Both Parents At Age 15	.10 (.07) [.01]	-.12** (.06) [-.03]	.05 (.06) [.02]

Continued on next page

Table 2 (cont'd): Demand for Prenatal Inputs

	Illicit Drug Use	Cigarette Smoking	First Trimester Prenatal Care
	Coefficient (Standard Error) [Marginal Effect]		
First Birth	.09 (.09) [.01]	.04 (.08) [.01]	.45*** (.10) [.17]
Number of Previous Pregnancies	.05 (.11) [.01]	.19* (.10) [.05]	.28*** (.10) [.11]
Attends Religious Services	-.24*** (.07) [-.03]	-.27*** (.07) [-.07]	-.01 (.08) [-.00]
% Under Poverty in Census Tract	.39* (.20) [.05]	.44 (.34) [.11]	-.02 (.16) [-.01]
Father Less Educated Than Mother	.36*** (.10) [.05]	.27*** (.07) [.07]	-.01 (.05) [-.00]
Father Different Race/Ethnicity Than Mother	.18** (.09) [.02]	.26** (.11) [.07]	.02 (.07) [.01]
Number of Years Father Older Than Mother	.02*** (.01) [.00]	.03*** (.01) [.01]	-.01* (.00) [-.00]
Mother Knew Father at Least 12 Months	.03 (.09) [.00]	-.06 (.07) [-.02]	-.10 (.07) [-.04]
Married at Time of Birth	-.46*** (.12) [-.04]	-.35*** (.09) [-.08]	.36*** (.06) [.14]
Mother Considered Abortion	.30*** (.11) [.04]	.29*** (.08) [.08]	-.34*** (.05) [-.14]
Pre-Existing Lung Disease	-.06 (.08) [-.01]	.02 (.07) [.00]	.00 (.10) [.00]

Continued on next page

Table 2 (cont'd): Demand for Prenatal Inputs

	Illicit Drug Use	Cigarette Smoking	First Trimester Prenatal Care
	Coefficient (Standard Error) [Marginal Effect]		
Other Pre-Existing Health Condition	-.12 (.09) [-.01]	.01 (.11) [.00]	.21** (.10) [.08]
History of Mental Illness	1.02*** (.12) [.21]	.56*** (.10) [.17]	-.10 (.09) [-.04]
STD During Pregnancy	.31*** (.10) [.04]	.12** (.06) [.03]	.08 (.05) [.03]
Pre-Pregnancy Underweight	-.12 (.20) [-.01]	.14 (.15) [.04]	-.12 (.17) [-.05]
Pre-Pregnancy Morbidly Obese	-.32 (.29) [-.03]	-.55* (.29) [-.11]	.14 (.24) [.05]
Pseudo R^2	.24	.19	.09
Pseudo R^2 in model w/o TUVs	.16	.17	.07
Increase in Pseudo R^2	50%	12%	29%
N	2638	2638	2638

*** significant at 1% level; ** significant at 5% level; * significant at 10% level
All models include city fixed effects.

Table 3: Reduced-Form Marginal Effects of TUVs on Infant Health Outcomes

	Birth Weight (grams)	Low Birth Weight (< 2500 grams)	Abnormal Infant Health Condition
	(1)	(2)	(3)
Considered Abortion	23.5 (25.2)	.001 (.013)	.018 (.013)
Pre-Existing Lung Disease	-24.0 (39.9)	.026* (.016)	-.006 (.018)
Other Pre-Existing Health Condition	-17.3 (67.2)	.046* (.030)	-.016 (.017)
History of Mental Illness	-116.5** (56.9)	.059*** (.023)	.034 (.019
STD During Pregnancy	-23.0 (32.9)	.021 (.016)	.045** (.011
Pre-Pregnancy Underweight	-110.2*** (34.1)	.027 (.031)	-.034 (.035)
Pre-Pregnancy Morbidly Obese	56.9 (83.5)	-.032 (.026)	-.015 (.054)
Mean	3221	.11	.12
N	2637	2638	2623
Actual or Pseudo R^2	.08	.09	.05
Actual or Pseudo R^2 w/o TUVs	.07	.07	.04

*** significant at 1% level; ** significant at 5% level; * significant at 10% level
TUV = typically unobserved variable
All models include city fixed effects.
Birth weight is estimated using OLS (standard errors in parentheses). Low birth weight and abnormal conditions are estimated using probit models; the marginal effects are presented with standard errors in parentheses.

Table 4: Quasi-Structural Models: Effects of Inputs and TUVs on Infant Health Outcomes

	Birth Weight (grams)	Low Birth Weight (< 2500 grams)	Abnormal Infant Health Condition
	(1)	(2)	(3)
Prenatal Illicit Drug Use	-120**	.02	.06***
	(53)	(.02)	(.03)
Prenatal Cigarette Smoking	-188***	.06***	-.01
	(30)	(.02)	(.02)
First Trimester Prenatal Care	23	-.01	-.00
	(20)	(.01)	(.01)
Considered Abortion	49*	-.01	.01
	(25)	(.01)	(.01)
Pre-Existing Lung Disease	-23	.03*	-.01
	(39)	(.02)	(.02)
Other Pre-Existing Health Condition	-20	.05*	-.01
	(65)	(.03)	(.02)
History of Mental Illness	- 46	.04**	.02
	(48)	(.02)	(.02)
STD During Pregnancy	-12	.02	.04***
	(33)	(.02)	(.01)
Pre-Pregnancy Underweight	-102***	.02	-.03
	(33)	(.03)	(.04)
Pre-Pregnancy Morbidly Obese	28	-.02	-.01
	(87)	(.03)	(.05)
Mean	3221	.11	.12
N	2637	2638	2623
Actual or Pseudo R^2	.10	.10	.05

***Significant at 1%, **5%, *10%

TUV = typically unobserved variable
Birth weight model is estimated using OLS (standard errors in parentheses). Low birth weight and abnormal conditions are estimated using probit models; the marginal effects are presented with standard errors in parentheses. All models include variables from Table 2 plus city fixed effects.

Table 5: Quasi-Structural Models: Effects of Prenatal Inputs on Infant Health

		Birth Weight (grams)	Low Birth Weight (< 2500 grams)	Abnormal Infant Health Condition
		(1)	(2)	(3)
Prenatal Illicit Drug Use	A	-120**	.02	.06**
	B	-128**	.04**	.07***
	C	-137**	.04**	.08***
	D	-155**	.05**	.10***
Prenatal Cigarette Smoking	A	-188***	.06***	-.01
	B	-189***	.06***	-.00
	C	-200***	.07***	-.00
	D	-232***	.08***	.01
First Trimester Prenatal Care	A	23	-.01	-.00
	B	19	-.01	-.01
	C	24	-.01	-.01
	D	62**	-.03***	-.04
Mean		3221	.10	.12
N		2637	2638	2623
Actual or Pseudo R^2	A	.10	.10	.05
	B	.10	.09	.04
	C	.08	.08	.04
	D	.09	.08	.04

***Significant at 1%, **5%, *10%

TUV = typically unobserved variable

Each figure represents the marginal effect of an input on an outcome. In each cell, results are presented from four different model specifications:

Model A: includes TUVs and all other covariates (from Table 2) plus city fixed effects

Model B: does not include TUVs; includes all other covariates plus city fixed effects

Model C: does not include TUVs; includes only standard covariates (maternal age, education, race/ethnicity, nativity, first birth, previous pregnancies, marital status, city fixed effects)

Model D: does not include TUVs; includes only standard covariates; uses self-reported inputs instead of measures of inputs that combine medical records and self-reports