The Impact of Traffic on Birth Outcomes

by

Joseph R. LeCates III

(Under the direction of Angela Fertig)

Abstract

Considering a child's health production function of mothers during pregnancy, I examine the impact of traffic on the incidence of low birth weight and the mechanisms by which the effect is made, specifically the number of prenatal care visits and planned delivery through labor induction or caesarian section for the first birth. Using the 2002 Natality Detail data file and the 2000 United States Census data, I merge city information to birth data in the largest 77 cities in the United States. The econometric results demonstrate that traffic does negatively impact birth weight and is statistically significant, though its small magnitude prevents economic significance. Finding that the number of prenatal care visits is reduced with more traffic, but also that traffic decreases the likelihood of induction of labor or caesarian section for the first birth, I conclude that the number of prenatal care visits is more likely the causal mechanism.

Index words: Birth outcomes, Traffic, Prenatal care, Low birth weight, Labor induction, First-birth caesarian section

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B.A., The University of Georgia, 2006

A Thesis Submitted to the Graduate Faculty
of The University of Georgia in Partial Fulfillment
of the
Requirements for the Degree

Master of Arts

Athens, Georgia

2006

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Dedication

With a great deal of appreciation, I dedicate this thesis to my parents, Joseph and Pamela LeCates, without whose unwavering support this work would not be a possibility; and to my brother, Daniel, whose induction was inspirational.

Acknowledgments

I would like to thank Angela Fertig for all of the valuable time, dedicated effort, and insightful guidance she gave in bringing this thesis to fruition; she has been a priceless resource. Additionally, I greatly appreciate the aid of David Mustard and Christopher Cornwell for their participation on my thesis committee, as well as their outstanding teaching and advising over the course of my undergraduate and graduate careers. For my affiliation with these esteemed individuals, and with the inspiring Myra Moore, challenging Theodore Shifrin, and illuminating Edward Azoff, I am truly grateful. Finally, I thank the University of Georgia's Foundation Fellowship Program for the exceptional support and wonderful opportunities I have been afforded during my time at the University.

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Chapter 1

Introduction

For drivers faced with a large amount of traffic congestion on roadways, a common concern is how someone in need of emergency medical care might reach the hospital. Indeed, few individuals have this fear to such an extent as expectant mothers, so fearful to begin delivery outside of a medical facility that health care practitioners often suggest having several routes to the hospital planned given the traffic conditions at the time labor begins. One of the greatest examples of this fear are pregnant women in Jacksonville, Florida, a city with the St. Johns river flowing directly through the center. Residents must utilize a number of bridges to traverse the city, and having a "baby on the bridge" is a legitimate concern as the bridges may freeze during winter and lift for ships to pass beneath throughout the entire year. What many physicians and their patients do in order to prevent this type of event from occurring is to plan labor, that is, schedule the patient to arrive at the medical facility at a certain time on a certain date and then inducing labor or performing a caesarian section.

With these concerns in mind, I question the impact which traffic has on birth outcomes, first examining whether it has a significant impact on the incidence of induction and caesarian section in first births. From there, I consider the broader impact, investigating whether traffic may actually reduce the number of prenatal care visits mothers choose to make. Bringing these two points together, I turn to the question of traffic's impact on birth outcomes, considering low birth weight as a representative outcome. Hence, this thesis investigates whether traffic has a significant impact on the incidence of low birth weight, and if so, does this come through the mechanism of a reduced number of prenatal care visits or an artificial termination of gestation by induction or caesarian section?

Studies concerning the impact of traffic on health outcomes are varied, with most being environmental health analyses. Künzli et al. (2000) estimate the impact of outdoor and traffic-related pollution on public health in Austria, France, and Switzerland, finding that air pollution caused 6% of total mortality or more than 40,000 cases per year, with half of that number directly attributable to motorized traffic. Using a cross-sectional study to examine whether road traffic in a large city has a negative effect on pulmonary function and respiratory symptoms in children, Wjst (1993) studied fourth-graders in Munich to find that high rates of road traffic indeed diminish forced expiratory flow and increase respiratory symptoms. Specifically concerning low birth weight, the Institute of Medicine's report (1985) is quite comprehensive and presents numerous studies defining the risk factors and implications for its incidence. Included among these risk factors are age, race, marital status, education, smoking, absent or inadequate prenatal care, and iatrogenic prematurity, which could include induction and caesarian section.

Of singular importance to this paper is the work of Evans and Lien (2005) in which the authors relate birth outcomes including the incidence of low birth weight, to a traffic situation, the 1992 Port Authority Transit strike in Allegheny county, Pennsylvania. Because of the exogenous source of variation in access to prenatal care, the analysis mimics the characteristics of a controlled experiment. They use the strike as an instrument for prenatal care in birth outcome equations, including low birth weight and length of pregnancy. Constructing a two stage least squares estimate of the benefits of prenatal care, they are unable to show with statistical significance any link between black women, the bus strike, and a reduction in the incidence of low birth weight. However, the authors do find statistically significant evidence that more prenatal care visits reduce maternal smoking during pregnancy, and that early prenatal care visits enhance birth weight. Overall, Evans and Lien conclude that "access to adequate transportation plays a significant role in the utilization of prenatal care."

By providing a direct link between traffic and birth outcomes, this thesis will make a number of important contributions to the literature. The first is an identification of another determinant of birth outcomes. As traffic is omitted in the vast majority of previous work on low birth weight, its addition may enhance the model by explaining certain health behaviors among mothers during pregnancy, as well as alter the marginal effects currently attributed to other explanatory variables. We may indeed find that certain risk factors are a smaller problem than previously considered. Thus, some of the effect usually attributed to race and ethnicity may actually be the result of a greater propensity of minorities to live in high traffic areas. With its identification, other investigations concerning low birth weight can control for its effect, giving more accurate results. Additionally, policymakers can apply the link between traffic and low birth weight to other situations in which the indirect effects of traffic may alter health outcomes.

For the remainder of this thesis, I plan to use the outline below. In the next chapter, I discuss a theoretical model which relates traffic to birth outcomes using a health production function. In chapter three, I describe the data and sample used in the analyses, while chapter four presents the empirical strategy I take to determine the marginal effects of traffic. Chapter four also provides the summary statistics of my sample. I present my results in chapter five, evaluating not only the statistical results, but the economic significance of any marginal effects. In the final chapter, I draw some conclusions, examine the limitations of this study, and discuss the policy implication of my results.

Chapter 2

Theory

The relationship between inputs and outputs universally known as a production function has widespread use in health economics, and a description of the production of health functions can be found in many texts. Most frequently, a measure of health status is a function of many variables, including health care, lifestyle, environment, and biological endowment, and takes the following form (Folland, Goodman, and Stano, 2004):

$$Health\ Status = f(Health\ Care, Lifestyle, Environment, Human\ Biology) \tag{2.1}$$

Additionally, this health production function model can be used with many different forms of production, including the production of newborn health.

In a production of newborn health function, I use birth weight as a measure of health status. Low birth weight has been widely studied primarily because it is a major determinant of infant mortality in the United States. As the Institute of Medicine states in its comprehensive 1985 publication *Preventing Low Birthweight*, "Most infant deaths occur in the first 4 weeks of life, the neonatal period, and most are a consequence of inadequate fetal growth, as indicated by low birth weight." Low birth weight is defined as 2,500 grams, or about 5.5 pounds, or less and signifies inadequate fetal growth resulting from prematurity, intrauterine growth retardation, or both. Prematurity results when the duration of pregnancy is less than 37 weeks from the last menstrual period of the mother, and intrauterine growth retardation occurs for poor fetal weight gain given an adequate period of fetal gestation. Additionally, low birth weight increases the risk of illness and is an important factor in the differences in neonatal mortality rates for various groups of the population (Institute of Medicine, 1985).

Hence, birth weight is an important and useful measure of health status for the modeling and estimation of reduced-form equations.

Given this information, I propose the production of newborn health function as

$$Birth\ weight = f(Adequate\ gestation, Growth\ rate, X) \tag{2.2}$$

where X is a set of endowments including the many factors included as controls in my analysis. Thus, this function accounts for the two causes of low birth weight. The most common cause of intrauterine growth retardation is maternal smoking during pregnancy (Kramer, 1987). In order to substantially prevent the incidence of low birth weight, medical associations recommend numerous prenatal care visits for pregnant women[1]. The purpose of prenatal care visits are to monitor the development of the fetus, detect potential risk factors to both mother and fetus, and promote good health behaviors. Hence, through monitoring and encouragement, prenatal visits further the goal of a successful pregnancy. Evans and Lien (2005) note that "There is, in fact, no shortage of evidence linking prenatal care to better birth outcomes...[and] the bulk of the evidence finds that women with more prenatal care visits have children with higher birth weights and lower rates of low weight births." As part of prenatal care, health care practitioners check for both adequate gestation and growth rates, so that both sufficient and effective visits ensure a normal birth weight. Hence, I expand our production of newborn health function by

$$Gestation = g(Number\ of\ Prenatal\ Care\ Visits), \tag{2.3}$$

and

$$Growth\ rate = h(Number\ of\ Prenatal\ Care\ Visits). \tag{2.4}$$

Now, having daily prenatal care visits is not optimal, not only because of cost, but because of time. Pregnant women face a time constraint in which they must make trade-offs between work, leisure, and time spent at prenatal visits, notated as

$$\overline{Time} = Work + Leisure + Prenatal\ Visits \tag{2.5}$$

[1] These medical associations include the American Medical Association and the American College of Obstetrics and Gynecology

where $\overline{Time}$ is the fixed amount of time the expectant mother can allocate between these activities. Under the constrained maximization, the time spent at prenatal care visits has a premium, which is increased by the amount of traffic faced in going to prenatal care visits. By adding

$$Prenatal\ Visits = j(Traffic) \tag{2.6}$$

we determine the mechanism by which traffic may affect the incidence of low birth weight through prenatal care visits: the expectant mother maximizes the health status, or the probability of an adequate birth weight of the newborn, by making sufficient prenatal care visits subject to a time constraint, causing traffic to have an impact on low birth weight by increasing the cost of obtaining prenatal care.

The other mechanism by which traffic may affect the incidence of low birth weight is through the artificial shortening of the period of gestation. A normal length of gestation is between 37 and 41 weeks from last menstrual cycle of the mother to birth, with any birth before 37 weeks being premature and any birth after 41 weeks being long term. When the pregnant woman's body begins regular uterine contractions, she is said to be "in labor", though the trigger for the onset of labor is unknown. However, physicians now regularly induce or stimulate labor so as to cause the pregnant women to go into labor if they consider the fetus to be sufficiently developed. A widely-accepted rule among physicians and health care practitioners is the induction of birth if the pregnancy reaches the forty-second week. By this stage, the fetus should have sufficiently developed to survive outside of the womb. Inductions are in effect artificial terminations of the period of gestation. Similarly, caesarian sections can be used to prematurely end the period of gestation by surgically removing the fetus from the mother. However, once a mother has had a caesarian section, the same procedure is frequently recommended on all subsequent births. For this reason, I only look at the incidence of caesarian sections for first born children.

The significance of these artificial terminations is their role in planning labor and delivery. One of the greatest fears of expectant mothers is the birth of the newborn outside of a birthing facility. In order to alleviate these fears, a physician may choose to schedule the delivery of the child, at which time she can induce the labor or perform a caesarian section. The fear of having a child outside of a birthing facility should be affected by traffic conditions. For example, the anecdotal evidence presented concerning the mothers needing to cross bridges in winter would demonstrate the increased fear because of traffic conditions. Hence, the other method by which traffic may affect low birth weight is through the termination of gestation through induction or primary caesarian section. Thus, I re-write equation 2.3 to include these factors as follows:

$$Gestation = g(Number\ of\ Prenatal\ Visits, Induction, Caesarian\ section) \tag{2.7}$$

and

$$Induction = m(Traffic) \qquad Caesarian\ section = n(Traffic). \tag{2.8}$$

From these production functions and constraints, I derive the econometric models specified below, controlling for exogenous variables which affect the outcomes.

Chapter 3

Data and Sample

In order to investigate the relationship between traffic and birth outcomes, data are needed with information on specific births and locations as well as the traffic information for the geographic area. The Natality Data Set, gathered by the National Center for Health Statistics, contains information for all recorded births in a given year, including geographic indicators for region, state, county, and city. With such information, the data can be merged with city-level traffic information provided by the United States Census Bureau from the 2000 Census of Population and Housing Demographic Profile. Together, these data sets provide sufficient information to investigate the effects of traffic on low birth weight, prenatal care, and planned labor and delivery.

I use the 2002 Natality Detail File because the data contain copious characteristics of the birth outcomes, the health and demographic characteristics of the child and parents, and because the file is the most recent publication of natality data. Most importantly, the file contains the specific city in which the birth occurred, allowing the matching with Census data. The information comes from the birth records as well as self-reported data on variables such as the number of prenatal visits. Of greatest interest among the variables are whether the weight of the newborn, the number of prenatal visits, and whether the labor was induced or a first-birth caesarian section. The many other variables, including age, race and ethnicity, years of education, and marital status of the mother, birth order, weeks of gestation, and tobacco use, provide excellent controls for the statistical regression.

The geographic data given by the Natality Detail File provides information on the region and state of the residence of every mother, though the type of local area must be taken into consideration. Because I do not wish to have urban versus non-urban nor small city versus large city confounding variables, the observations are restricted to those individuals which live in the 77 largest cities in the United States. These cities are those with more than 200,000 residents and generally constitute large urban areas. As county and city information is given for mothers in areas of more than 100,000 residents, I am able to select just those births occurring in the 77 cities. In total, the 2002 Natality Data Set contains information on the 4,027,376 births which occurred in 2002, while the number of births in the largest cities is 906,068.

For traffic information on those 77 cities, the U.S. Census Bureau collects information on travel time to work as part of the Census of Population and Housing Demographic Profile. Travel time to work refers to the total time it took an individual to go from home to work each day during the reference week, including time spent waiting for public transportation, picking up passengers in carpools, and time spent on other activities related to getting to work. The data were collected on members of the working population, ages 16 and older who reported working outside of the home. While this measure does not directly indicate the amount of traffic volume experienced by pregnant women making pregnancy decisions, mean travel time to work indicates the distances individuals travel and the amount of time necessary to travel to a specific location, rendering a proxy for the level of traffic in the area. This information is readily available on the Census Bureau's web site through the FactFinder State and Local QuickFacts. Thus, for all residents in the selected 77 cities, I am able to identify and merge the data for local traffic conditions.

Chapter 4

Empirical Strategy

In order to determine the impact of traffic on birth outcomes, I use a cross-sectional econometric model to isolate the marginal effect of traffic. The dependent variables of interest are whether the newborn had a low birth weight, the number of prenatal visits made by the mother, whether the birth was induced, and whether the delivery method was by caesarian section for the first-born child. I restrict the sample to first births when using caesarian section as the dependent variable because mothers having a second caesarian section may be undergoing this birthing method only because of the physical result of a previous caesarian section and not because of some desire to plan the birth. Traffic varies across cities (c) and the outcomes are measured at the individual level (i). Thus, I estimate four equations of the following form – one for each of the four dependent variables.

$$Y_{ic} = \beta_0 + \beta_1 * TRAFFIC_c + X_i\beta_2 + \varepsilon_{ic} \tag{4.1}$$

Because the number of prenatal visits is a non-negative count variable, I estimate the above equation by Poisson maximum likelihood (ML). Because the other three dependent variables are dichotomous, I apply probit ML to the above equation. In this equation, β_0 is a constant, *TRAFFIC* represents the amount of traffic congestion with the mean travel time to work for the city, X is a vector of the demographic and health characteristics of the mother and child, and ε_{ic} is a random error term. Hence, β_1 measures the marginal effect of a minute of traffic on the outcome, though the coefficient must be transformed in order to see the marginal effect on the probability of the outcome in the probit models. I adjust the standard errors for intra-cluster correlations within states for all of the analyses.

The control variables included in X are binary variables for race and Hispanic origin, whether the mother was married, the sex of the child, whether the mother smoked during pregnancy, whether the child is the first-born, and six levels of education completed (education not reported, junior high school, some high school, high school, some college, and college), as well as the age of the mother and its squared value, and the number of weeks of gestation. Race and ethnicity are divided into white non-Hispanic, black non-Hispanic, Hispanic, and other races and ethnicities, so that white non-Hispanics are the omitted group. For marital status, gender of the child, maternal smoking, and level of education, the single, female, non-smoker, and high school graduate groups will be the omitted groups during estimation. The age of the mother and its squared value are included to allow for nonlinear effects. I choose to include these variables in the estimation equation because they have been shown in other works to act as cofactors in birth outcomes (Kramer, 1987). The length of time of the gestation period is important because it controls for the amount of time the fetus has to grow and gain weight as well as the time a mother has to make prenatal visits, and it is therefore included in all regressions. However, because a large proportion of the literature on low birth weight excludes a control for the number of weeks of gestation, leaving the indicator unadjusted, we also estimate a probit model of low birth weight without controlling for gestation in order to make comparisons with previous work.

Summary statistics of the samples used for the analyses are presented in Tables 4.1 and 4.2, for all births and first births in 2002, respectively. In addition, the national averages for 2002 are included. For all births, newborns with low birth weights comprise 7.8% of population, which is consistent with the national average at roughly eight percent. The average number of prenatal care visits is 11.59, which is within the range suggested by the various medical associations and consistent with the national average. At 18.55%, the mean for inductions in 2002 is slightly smaller than the national average, though close in magnitude. The city traffic data range from 18.1 minutes of average travel time to work to 40 minutes, with a mean of 27 minutes and 46 seconds. The racial and ethnic characteristics of the sample are approximately 48% white non-Hispanic, 17% black non-Hispanic, 27% Hispanic, and 8% other races and ethnicities. While the Hispanic population seems greater than expected, this mean results from the greater number of children that Hispanic mothers have on average. Sixty-six percent of the mothers were married, and mothers have an average age of 27.87 years, which are in line with the national average. Although 8.29% of mothers reported smoking at some time during their pregnancy, the actual percentage is likely higher due to underreporting. About 40% of newborns were their mother's first birth, and gestation lasted 38.69 weeks on average, both of which are expected means. Finally, the education distribution of the mothers falls near the national average, though is slightly more educated overall and especially in the attainment of a college education.

When considering only first-births, the statistics are similar for all characteristics. However, one should note that the percentage of low birth weight was higher, as was the number of prenatal visits and the percentage of labors induced as compared to all births of the 77 cities, which offers supporting evidence to my hypothesis that first-births are innately different from subsequent births. Also, the rate of caesarian section is 26.70%, again quite close to the national average. Mothers of first-born children tend to be younger at 25.74 years, less likely to be married with only 60% percent married, less likely to smoke as 6.75% report smoking, and have slightly longer periods of gestation, averaging 38.84 weeks.

While the Natality Detail File provides copious information on the birth process and health status of the mother and child, the data lack certain information for which one might normally control. The file does not provide any indicator of income, necessarily eliminating it. Additionally, the quality of the drinking data has been shown to be poor (Evans and Ringel, 1999). As a result, I take the same approach as other works by excluding the measure of maternal drinking in estimation (Evans and Lien, 2005).

Table 4.1: Summary Statistics, 77 Cities, All Births

Variable	Natl. Mean	Mean	Std. Dev.	Min.	Max.
Low Birth Weight	0.0781	0.0782	0.2686	0	1
No. Prenatal Visits	11.5330	11.5971	4.0443	0	49
Induced	0.2062	0.1855	0.3887	0	1
City Traffic		27.7639	6.0943	18	40
Black Non-Hispanic	0.1436	0.1656	0.3717	0	1
Hispanic	0.2177	0.2688	0.4433	0	1
Other Races & Ethn.	0.0681	0.0834	0.2765	0	1
Married	0.6605	0.6605	0.4735	0	1
Male	0.5117	0.5114	0.4999	0	1
Smoker	0.1143	0.0829	0.2758	0	1
Education Not Reported	0.0153	0.0182	0.1337	0	1
Junior High School	0.0578	0.0642	0.2452	0	1
Some High School	0.1530	0.1492	0.3563	0	1
Some College	0.2117	0.2004	0.4003	0	1
College	0.2554	0.2854	0.4516	0	1
Mother's Age	27.3366	27.8747	6.2331	11	54
Weeks of Gestation	38.6845	38.6868	2.5831	17	47
First Birth	0.3976	0.4028	0.4905	0	1

Table 4.2: Summary Statistics, 77 Cities, First Births

Variable	Natl. Mean	Mean	Std. Dev.	Min.	Max.
Low Birth Weight	0.0781	0.0823	0.2748	0	1
No. Prenatal Visits	11.5330	11.8278	3.9408	0	49
Induced	0.2062	0.2109	0.4080	0	1
Caesarian Section	0.2592	0.2670	0.4424	0	1
City Traffic		27.9522	6.2350	18.1	40
Black Non-Hispanic	0.1436	0.1555	0.3623	0	1
Hispanic	0.2177	0.2455	0.4304	0	1
Other Races & Ethn.	0.0681	0.0966	0.2954	0	1
Married	0.6605	0.5999	0.4899	0	1
Male	0.5117	0.5128	0.4998	0	1
Smoker	0.1143	0.0675	0.2509	0	1
Education Not Reported	0.0153	0.0171	0.1296	0	1
Junior High School	0.0578	0.0467	0.2111	0	1
Some High School	0.1530	0.1485	0.3556	0	1
Some College	0.2117	0.1961	0.3971	0	1
College	0.2554	0.3249	0.4683	0	1
Mother's Age	27.3366	25.7365	6.2628	11	54
Weeks of Gestation	38.6845	38.8354	2.6250	17	47

Chapter 5

Results

I motivate this thesis by considering whether traffic has a significant impact on birth weight, specifically the incidence of low birth weight, by reducing the number of prenatal visits and increasing inductions and first-birth caesarian sections. As the results demonstrate, this hypothesis is correct, yet the latter mechanisms have the opposite effects than what I predicted. One of the greatest advantages of using the Natality Detail data files is the large number of observations. In the econometric analyses involving low birth weight, the number of prenatal visits, and induction of labor, I use over 700,000 observations, while nearly 300,000 observations are used in the analysis of first-birth caesarian sections. The result of the large numbers is that I am able to measure the effects with a great deal of precision. Hence, nearly all of the regressors are statistically significant. Therefore, I will additionally consider the size of the marginal effects to determine their economic significance.

Starting with the main dependent variable of interest, I examine gestation adjusted incidence of low birth weight in a probit model, the results of which are presented in the first column of Table 5.1. The measure of traffic has a marginal effect of 0.0002 percentage points. Because 7.82% of the newborns in our sample have a low birth weight, traffic's marginal effect of 0.0002 percentage points per minute corresponds to a $0.0002 \div 0.0782 = 0.00256$ or 0.256% increase in the probability of having a low birth weight for each additional minute of traffic faced. Thus, if a mother moved from Wichita, Kansas, the city with the lowest average commute time at 18.1 minutes, to New York City, which has an average commute time of 40 minutes, the model predicts that her newborn will have a $(40 - 18.1) * 0.00256 = 0.0561$ or 5.61% greater chance of having a low birth weight. Alternatively, for a ten percent greater

Table 5.1: Reduced-form Results for Low Birth Weight

Dependent Variable	(1)	(2)	(3)
City Traffic	0.0002**	0.0001+	
	(0.0001)	(0.0001)	
Black Non-Hispanic	0.0242**	0.0320**	0.0247**
	(0.0019)	(0.0017)	(0.0018)
Hispanic	-0.0015+	-0.0004	-0.0011
	(0.0008)	(0.0013)	(0.0009)
Other Races & Ethn.	0.0105**	0.0127**	0.0111**
	(0.0014)	(0.0016)	(0.0016)
Married	-0.0072**	-0.0180**	-0.0084**
	(0.0007)	(0.0007)	(0.0007)
Male	-0.0163**	-0.0165**	-0.0163**
	(0.0006)	(0.0006)	(0.0007)
Smoker	0.0405**	0.0542**	0.0344**
	(0.0016)	(0.0016)	(0.0015)
Education Not Reported	0.0010	0.0051+	0.0020*
	(0.0018)	(0.0027)	(0.0012)
Junior High School	-0.0035	-0.0048*	-0.0022
	(0.0022)	(0.0022)	(0.0018)
Some High School	0.0019**	0.0033+	0.0023**
	(0.0005)	(0.0006)	(0.0004)
Some College	-0.0028**	-0.0034*	-0.0026**
	(0.0009)	(0.0010)	(0.0006)
College	-0.0042**	-0.0044**	-0.0038**
	(0.0010)	(0.0012)	(0.0007)
Mother's Age	-0.0022**	-0.0027**	-0.0019**
	(0.0004)	(0.0004)	(0.0004)
Mother's Age Squared	0.0000**	0.0000**	0.0000**
	(0.0000)	(0.0000)	(0.0000)
First Birth	0.0131**	0.0084**	0.0133**
	(0.0015)	(0.0015)	(0.0014)
Weeks of Gestation	-0.0283**		-0.0285**
	(0.0004)		(0.0004)
Observations	729411	731771	729411

Marginal effects reported. Numbers in parentheses are robust standard errors. Statistical significance is denoted as follows:
+ significant at 10 %; * significant at 5 %; ** significant at 1 %

chance of having a low birth weight, the change in traffic must be $0.10 \div 0.00256 = 39.06$ minutes more. Because the greatest average commute time reported is 40 minutes in New York City, this effect does not seem to present a substantial problem to a mother moving between any of the large cities. However, one can easily imagine a rural resident moving to a highly congested city area where this might occur. Nevertheless, while the result is statistically significant at the one percent level, the magnitude of the effect of traffic on the incidence of low birth weight does not seem to be economically significant.

The second column in Table 5.1 is also a probit regression with low birth weight as the dichotomous dependent variable, but this time it is not adjusted for weeks of gestation. This specification has been more widely used in previous work than gestation adjusted low birth weight, though the latter has been recently incorporated into the literature, and so I consider unadjusted low birth weight here. The measure of traffic is again statistically significant with marginal effect of 0.0001, though only at the ten percent level. Here, the marginal effect of 0.0001 translates into an increased probability of low birth weigh by only $0.0001 \div 0.0782 = 0.00128$ or 0.128% for each additional minute of traffic. This supports the conclusion that traffic is not economically significant. The many control variables and covariates are generally similar to their estimates in the adjusted case, and each variable has the same sign, though statistical significance does not correspond as well. Overall, this difference may be evidence for the gestation-adjusted specification, though the similarities point to a well-identified model.

Among the results for the control variables, focusing on the first estimation, I find the results consistent with previous work. Being black increases the probability of a low birth weight by more than 30 percent, and is statistically significant, while Hispanics tend to have a lower incidence of low birth weight though the result is not as significant. This latter result is consistent with current research as exemplified by Buekens, et al. (2000). Married and more highly educated women have a significantly lower incidence of low birth weight, as do older women, though the effect is nonlinear. First-born children are also more likely to have lower birth weight, though this is primarily attributed to the reproductive health of the mother during the first pregnancy (Institute of Medicine, 1989). Male newborns also are less likely to have a low birth weight. By far the most profound cause of low birth weight is smoking by the mother during pregnancy. A mother who smokes increases the risk of having a child with low birth weight by 51.79%. In comparison, an unmarried mother is more than 9% more likely and a first-born child is almost 17% more likely to have a low birth weight. Of these statistically significant results, all of the coefficients lead us to conclude that they are substantially more economically significant than the amount of traffic.

The third specification of the probit maximum likelihood omits traffic as an explanatory variable in order to demonstrate the importance of its inclusion in birth outcome models. Current practice in birth outcome models does not include traffic, as it has not been identified as a significant factor. However, should traffic be identified as such a factor, than it should be included in reduced-form regressions so as to avoid an omitted variables bias. Additionally, if traffic explains some of the variation in birth weight which is currently attributed to other factors, the marginal effects of those variables may change. This specification gives the opportunity to observe the differences caused by adding traffic to the model.

While the marginal effect of being black is extremely close to its value when traffic is included, the marginal effect of Hispanic loses any significance when city traffic is not included. However, even though the marginal effect is not statistically significant, the decreased probability of low birth weight among Hispanics is in agreement to the finding by Buekens, et al. (2000). The other differences include a dramatic decrease in the marginal effect of smoking. With a coefficient of 0.0344, smoking during pregnancy increases the risk of low birth weight by $0.0344 \div 0.0782 = .4399$ or nearly 44%, as opposed to the 51.79% reported when traffic is included. Thus, smoking is shown to have an even greater impact when traffic is included. Finally, the exclusion of traffic has an impact on lower education levels, causing them to appear greater than actual values. Overall, these changes in the marginal effects appear to have significant economic consequences, leading to the conclusion that traffic should be included in models for birth outcomes to prevent any omitted variables bias.

While the magnitude of the effect of traffic may be small when it is included as a factor, the coefficient is certainly statistically significant, and with the remaining three regressions, I look for a mechanism which causes this significance. The results of these analyses are presented in Table 5.2 and show the marginal effects. Prenatal visits could directly prevent the occurrence of low birth weight as several examinations are given in order to identify conditions leading to low birth weight. Again, in this Poisson count data model, the effect of traffic is statistically significant at one percent with the marginal effect of -0.0063. This result signifies that for every additional minute of traffic faced, the mother will have 0.0063 fewer prenatal visits. This means that the mother moving from Wichita to New York City is expected to have $(40-18.1)*0.0063 = .138$ fewer prenatal care visits. Again, I conclude that, while the coefficient on traffic is statistically significant, traffic is not economically significant in that the tradeoff between traffic and prenatal visits is not large. One would find it difficult to imagine any situation when average commute time would exceed two and a half hours, the amount of time necessary in order to expect one fewer prenatal visits.

The remainder of the regression coefficients, however, match with previous work on prenatal care (Evans and Lien, 2005). Minority mothers and those with lower levels of education typically receive a smaller number of prenatal visits. Simultaneously, older, married, and more educated women, as well as those mothers preparing for their first birth, receive significantly more prenatal care with a greater number of visits. Additionally, with each additional week of gestation, the mother is expected to receive 0.019 more prenatal care visits, which nears one as the birth goes toward long term[1]. These results are truly more economically significant than the amount of traffic present in the area. The only statistically significant result which appears unexpectedly is that male children receive fewer prenatal care visits. While

[1]In this estimation as well as those for induction and first-birth caesarian section, the control for weeks of gestation is included as it is in Evans and Lien (2005). However, its absence does not significantly alter the estimated coefficients on neither traffic nor any of the control variables.

Table 5.2: Reduced-form Results for Causal Mechanisms

Dependent Variable	Prenatal Visits	Induced	1^{st} C-Sect.
City Traffic	-0.0063**	-0.0042**	-0.0013*
	(0.0015)	(0.0009)	(0.0006)
Black Non-Hispanic	-0.0408**	-0.0282**	0.0619**
	(0.0123)	(0.0107)	(0.0054)
Hispanic	-0.0496**	-0.0459**	0.0240**
	(0.0120)	(0.0071)	(0.0085)
Other Races & Ethn.	-0.0701**	-0.0583**	-0.0116+
	(0.0110)	(0.0062)	(0.0062)
Married	0.0512**	-0.0001	-0.0051*
	(0.0069)	(0.0049)	(0.0023)
Male	-0.0029**	0.0020**	0.0303**
	(0.0007)	(0.0006)	(0.0016)
Smoker	-0.0971**	0.0159*	0.0223**
	(0.0094)	(0.0070)	(0.0047)
Education Not Reported	-0.1277**	-0.0055	-0.0383**
	(0.0142)	(0.0117)	(0.0123)
Junior High School	-0.0999**	-0.0374**	-0.0129
	(0.0239)	(0.0112)	(0.0087)
Some High School	-0.0596**	-0.0145*	-0.0033
	(0.0064)	(0.0068)	(0.0059)
Some College	0.0389**	0.0191**	0.0086+
	(0.0062)	(0.0023)	(0.0051)
College	0.0372**	0.0032	-0.0243**
	(0.0062)	(0.0053)	(0.0073)
Mother's Age	0.0141**	0.0033**	0.0152**
	(0.0014)	(0.0005)	(0.0015)
Mother's Age Squared	-0.0002**	-0.0000**	-0.0000
	(0.0000)	(0.0000)	(0.0000)
Weeks of Gestation	0.0190**	0.0119**	-0.0047**
	(0.0007)	(0.0004)	(0.0004)
First Birth	0.0526**	0.0502**	
	(0.0027)	(0.0035)	
Constant	1.5867**		
	(0.0597)		
Observations	703615	729083	297844

Marginal effects reported. Numbers in parentheses are robust standard errors. Statistical significance is denoted as follows:
+ significant at 10 %; * significant at 5 %; ** significant at 1 %

the number is so small as to question its economic significance, this result may relate back to the lower incidence of low birth weight in male children and subsequently a reason to have fewer visits for a male child.

The other mechanism by which I expected the amount of traffic to increase the incidence of low birth weight is planned labor, in which a mother would essentially schedule the birth and delivery. This method, believed to result from a fear of having a birth outside of a medical facility because of an inability to reach the hospital in traffic, would seem to bring about the birth prior to its natural occurrence. Thus, induction of labor and first-birth caesarian sections would increase the likelihood of a low birth weight, which I consider in the last two columns of Table 5.2. Observing nearly 730,000 births, econometric analysis of the impact on traffic on induction of labor shows that traffic is statistically significant at one percent, though the opposite sign of what was expected. The marginal effect of a minute of traffic in average commute time is -0.0042 percentage points, which corresponds to being $-0.0042 \div 0.1855 = -0.0226$ or 2.26% less likely to have the mother's labor induced as 18.55% of the sample has an induced labor. Hence, we see that births in cities with higher traffic are actually less likely to be induced. Additionally, the marginal effect has the potential to be economically significant. The expectant mother moving from Wichita to New York City is now $(40 - 18.1) * -0.0226 = -0.4949$ or 49.49% less likely to have her labor induced. The result here is unexpected and may result because of some differences between those cities with large amounts of traffic and those without much traffic.

In order to determine if the regression is flawed in some way, I can evaluate the marginal effects reported for the other independent variables. Minority mothers are much more likely to have naturally occurring births as black, Hispanic, and other racial and ethnic minority mothers are roughly 3, 5, and 6 percent less likely to be induced, respectively. These estimates are reasonable given previous work on the reduced access to care for minorities. The more education the mother had the more likely she is to be induced, as are older women. As suspected, the greater the number of weeks of gestation, the more likely the mother is to be induced, especially when considering the procedure is normally implemented for periods of gestation greater than 42 weeks. Physically, mother's first birth is more likely to be induced because the mother's body has not experienced reproduction and therefore the first pregnancy tends to have a longer period of gestation (Institute of Medicine, 1989). Overall, the other results appear to follow their expected patterns, which bolsters the support for the marginal effect on the amount of traffic.

A comparable situation to the induction of labor is found when I consider the occurrence of caesarian sections on first birth mothers. Again traffic actually reduces the probability of a caesarian section by $0.0013 \div 0.267 = 0.00487$ or 0.487% for each minute as the marginal effect of traffic is -0.0013 percentage points and 26.7% of the first births are delivered by caesarian section. Alternatively, the probability of a caesarian section on a first birth decreases by 1% every $.01 \div 0.00487 = 2.05$ minute increase in average commute time. The result is statistically significant, though at the five percent level. However, as I consider the rest of the results to ascertain the viability of this model as a good model of caesarian section on first births, the results are not always as one would expect from previous medical and economic work. Black and Hispanic mothers are more likely to have a caesarian section, at 23.18% and 8.99% respectively, though those mothers of other races and ethnicities are less likely to have a caesarian section by 6.22%. While these results are statistically significant, they may contradict the evidence of lower access to care (Bodenheimer and Grumbach, 2002). Nearly all levels of education are less likely to have lower probabilities of incidence, yet only the extreme lower and upper levels are statistically significant. In line with expectations are older mothers, who have a statistically significant greater probability of having caesarian sections on their first delivery, and mothers who smoke, who have a statistically significant greater incidence of the procedure. As the results are a combination of those expected and those which are not, the estimation may imply that the need for caesarian sections on first births is a complicated decision involving a number of health characteristics of the mother.

In consideration together as an argument for the planning of labor and delivery, the last two regressions demonstrate that traffic does not seem to reduce gestation length through induction or caesarian section on the first birth, since the marginal effects actually decrease the likelihood of their incidence instead of increasing them. For an explanation, one should consider whether there are some innate differences between those cities with greater amounts of traffic and those with less traffic. One potential aspect may be that the average commute time of a city is positively correlated with wealth for the city's residents. For investigation of this potential explanation, fixed effects models for the state and city, depending on the level of the data, would potentially uncover this result.

Chapter 6

Conclusion

In this paper, I use the 2002 Natality Detail data file and mean travel time to work for the 77 largest cities in the United States as given by the U.S. Census Bureau from the 2002 Census, to estimate the impact of traffic on birth outcomes, specifically looking at the incidence of low birth weight. Upon finding that traffic does indeed increase the probability of a low birth weight, I further investigate the mechanism by which this occurs: through a reduction in the number of prenatal visit, and an artificial termination of gestation via induction of labor or caesarian section on the first birth. These pathways were chosen after hypothesizing a health production function for pregnancy and the manner in which healthy birth weight is achieved. The econometric analysis of the probit model for low birth weight adjusted for weeks of gestation reveals that traffic does increase the probability of having a low birth weight and is statistically significant. However, each additional minute of average travel time only increases the probability 0.256%, which makes it economically insignificant. A similar though even less economically significant marginal effect from traffic results when the model is unadjusted for gestation period. When traffic is omitted entirely, some marginal effects are changed, most notably smoking, which suggests that traffic should be included in all specifications to avoid omitted variables bias.

Because of the statistical significance, I consider the mechanisms by which this increase in the probability of low birth weight occurs, finding that traffic does decrease the number of prenatal care visits made by mothers, but actually decreases the likelihood of a shortened period of gestation through induction of labor or caesarian section on the first birth. When I consider the economic significance of traffic on these dependent variables, I find that traffic remains a relatively insignificant factor. The other covariates, specifically smoking, being married, and being the first birth, are all much more economically significant than traffic, even when the difference is considered between the cities with the highest and lowest average commute times. Hence, the process by which traffic affects low birth weight is more likely through the mother's health behaviors such as doctor's visits, which affect the fetal growth rate, rather than planning or inducing the labor and delivery, which affects the length of the gestation period.

The limitations of this analysis come from two principal sources: the measure of traffic and the absence of important control variables. The first concern initially develops as a result of the level of the data. Although I was only able to obtain traffic data for the city overall and I use it in my regressions, I realize that intra-city variation among average commute times exists to nearly the same degree as variation across cities. At a more refined level of data, such as the county level, I might more accurately understand the effect that traffic has on birth outcomes and pregnancy decisions. One could expect that these decisions are made more at a local level than city-wide, with distance to the hospital or birthing center playing a large role in decision-making. Still, I believe the results of an analysis using lower-level data would bolster those results reported here. While concern over the level of the measure of traffic is a limitation, a larger issue exists with regards to the measure itself. While I believe that average commute time speaks to the overall amount of traffic faced by residents of a particular area, the measure remains a proxy for the actual amount of traffic faced by the mother in her individual situation. Finding a data set where distance to a hospital, time spent driving to visits to the health care practitioner's office, or some indication of the traffic conditions faced by an expectant mother is included with the birth outcomes and health characteristics of the mother would solve this problem.

The second limitation of this study exists because of a lack of certain control variables. The two controls most apparently absent are the amount of maternal alcohol consumption and an indication of the income or wealth of the mother, both of which are identified by the Institute of Medicine as principal risk factors for low birth weight. Alcohol consumption has potentially profound effects on the outcome of a pregnancy, with fetal alcohol syndrome and intrauterine growth retardation, both leading to a greater incidence of low birth weight, as the most prominent(Ouellette, 1977). While alcohol consumption is reported within the Natality Detail data file, the measurement of the statistic is not as uniform as for smoking. Not every state collects information on maternal alcohol consumption when preparing the birth certificate, which causes either a significant decrease in the number of observations or a weakening of the estimation to accurately control for consumption if those observations are included. The other major risk factor for low birth weight is poverty, with income or wealth having a potential impact on the incidence of low birth weight and the number of prenatal visits made by the mother (Horon, Strobino, and MacDonald, 1983). While a public health care system, such as Medicare, Medicaid, and local health departments, reduces some of the disparities among different levels of income, access to care is still shown to be better for those with higher incomes. Unfortunately, income is not reported as part of the Natality Detail file. Again, a focused data set containing birth certificate information as well as an indicator of income is the most likely solution. However, I do have education, age, and race and ethnicities, which are all good proxies for income and which maintain the importance of my results.

The results of this analysis, even without perfect controls, have significant policy implications. While environmental health studies which link increased amounts of traffic to health outcomes such as lung cancer via pollution abound, the literature on the indirect effects of traffic congestion on health outcomes is virtually nonexistent. This thesis, however, makes a clear connection between the amount of traffic in an area, and one of the most closely analyzed health outcomes, low birth weight, showing that more traffic is associated with a greater likelihood of low birth weight, with a reduced number of prenatal visits in traffic dense cities being the likely cause for this association. The identification of traffic as a statistically significant factor may cause the need to reevaluate currently policies based on earlier findings which did not take the impact into consideration. In addition, this paper highlights the disparities in health and in access to health care in cities, where traffic can become a concern to residents. The cause of the disparity here is demographic makeup of cities, which contain larger populations of impoverished and minority populations, groups that have historically received less access to care and lower quality care. Hence, policymakers should consider not only the direct results policies have on health through the amount of pollution caused by traffic, but the indirect implications traffic has through altered decisions health consumers make, especially for those who may already be disadvantaged in the health care market.

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