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TRAFFIC CONGESTION AND INFANT HEALTH: EVIDENCE FROM E-ZPASS

Janet Currie
Reed Walker

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ABSTRACT

This paper provides evidence of the significant negative health externalities of traffic congestion. We exploit the introduction of electronic toll collection, or E-ZPass, which greatly reduced traffic congestion and emissions from motor vehicles in the vicinity of highway toll plazas. Specifically, we compare infants born to mothers living near toll plazas to infants born to mothers living near busy roadways but away from toll plazas with the idea that mothers living away from toll plazas did not experience significant reductions in local traffic congestion. We also examine differences in the health of infants born to the same mother, but who differ in terms of whether or not they were "exposed" to E-ZPass. We find that reductions in traffic congestion generated by E-ZPass reduced the incidence of prematurity and low birth weight among mothers within 2km of a toll plaza by 10.8% and 11.8% respectively. Estimates from mother fixed effects models are very similar. There were no immediate changes in the characteristics of mothers or in housing prices in the vicinity of toll plazas that could explain these changes, and the results are robust to many changes in specification. The results suggest that traffic congestion is a significant contributor to poor health in affected infants. Estimates of the costs of traffic congestion should account for these important health externalities.

Janet Currie
International Affairs Building
Department of Economics
Columbia University - Mail code 3308
420 W 118th Street
New York, NY 10027
and NBER
jc2663@columbia.edu

Reed Walker
Graduate School of Arts and Sciences
Department of Economics
Columbia University
1022 International Affairs Building
New York, NY 10027
rw2157@columbia.edu

Motor vehicles are a major source of air pollution. Nationally they are responsible for over 50% of carbon monoxide, 34 percent of nitrogen oxide (NO_x) and over 29 percent of hydrocarbon emissions in addition to as much as 10 percent of fine particulate matter emissions (Ernst et al., 2003). In urban areas, vehicles are the dominant source of these emissions. Furthermore, between 1980 and 2003 total vehicle miles traveled (VMT) in urban areas in the United States increased by 111% against an increase in urban lane-miles of only 51% (Bureau of Transportation Statistics, 2004). As a result, traffic congestion has steadily increased across the United States, causing 3.7 billion hours of delay by 2003 and wasting 2.3 billion gallons of motor fuel (Schrank and Lomax, 2005). Traditional estimates of the cost of congestion typically include delay costs (Vickrey, 1969), but they rarely address other congestion externalities such as the health effects of congestion.

This paper seeks to provide estimates of the health effects of traffic congestion by examining the effect of a policy change that caused a sharp drop in congestion (and therefore in the level of local motor vehicle emissions) within a relatively short time frame at different sites across the Northeast United States. Engineering studies suggest that the introduction of electronic toll collection technology, called E-ZPass in the Northeast, reduced delays at toll plazas by more than 85 percent in the first year of adoption (New Jersey Turnpike Authority, 2001). We study the effect of E-ZPass, and thus the sharp reductions in local traffic congestion, on the health of infants born to mothers living near toll plazas.

This question is of interest for three reasons. First, there is increasing evidence of the long-term effects of poor health at birth on future outcomes. For example, low birth weight has been linked to future health problems and lower educational attainment (see Currie (2009) for a summary of this research). The debate over the costs and benefits of emission controls and traffic congestion policies could be significantly impacted by evidence that traffic congestion has a deleterious effect on fetal health. Second, the study of newborns overcomes several difficulties in making the connection between pollution and health because, unlike adult diseases that may reflect pollution exposure that occurred many years ago, the link between cause and effect is immediate. Third, E-ZPass is an interesting policy experiment because, while pollution control was an important consideration for policy makers, the main motive for consumers to sign up for E-ZPass is to reduce travel time. Hence, E-ZPass offers an example of achieving reductions in pollution by bundling emissions reductions with something consumers perhaps value more highly such as reduced travel time.

Our analysis improves upon much of the previous research linking air pollution to fetal health as well as on the somewhat smaller literature focusing specifically on the relationship between residential proximity to busy roadways and poor pregnancy outcomes. Since air pollution is not randomly assigned, studies that attempt to compare health outcomes for populations exposed to differing pollution levels may not be adequately controlling for confounding determinants of health. Since air quality is capitalized into housing prices (see Chay and Greenstone, 2003) families with higher incomes or preferences for cleaner air are likely to sort into locations with better air quality, and failure to account for this sorting will lead to overestimates of the effects of pollution. Alternatively, pollution levels are higher in urban areas where there are often more educated individuals with better access to health care, which can cause underestimates of the true effects of pollution on health.

In the absence of a randomized trial, we exploit a policy change that created large local and persistent reductions in traffic congestion and traffic related air emissions for certain segments along a highway. We compare the infant health outcomes of those living near an electronic toll plaza before and after implementation of E-ZPass to those living near a major highway but further away from a toll plaza. Specifically, we compare mothers within 3 kilometers (or 2 kilometers) of a toll plaza to mothers who are further away from a toll plaza but still within 3 kilometers of a major highway before and after the adoption of E-ZPass in New Jersey and Pennsylvania.

New Jersey and Pennsylvania provide a compelling setting for our particular research design. First, both New Jersey and Pennsylvania are heavily populated, with New Jersey being the most densely populated state in the United States and Pennsylvania being the sixth most populous state in the country. As a result, these two states have some of the busiest interstate systems in the country, systems that also happen to be densely surrounded by residential housing. Furthermore, we know the exact addresses of mothers, in contrast to many observational studies which approximate the individual's location as the centroid of a geographic area or by computing average pollution levels within the geographic area. This information enables us to improve on the assignment of pollution exposure. Our research design also exploits the fact that E-ZPass was installed at different times and in different locations across the two states, allowing us to flexibly control for time trends in infant health while still being able to identify our model. Lastly, E-ZPass adoption and take up was extremely quick, and the reductions in congestion spillover to all automobiles, not just those registered with E-ZPass (New Jersey Transit Authority, 2001).

Our first difference-in-differences research design relies on the assumption that the characteristics of mothers near a toll plaza change over time in a way that is comparable to those of other mothers who live further away from a plaza but still close to a major highway. We test this assumption by examining the way that observable characteristics of the two groups of mothers and housing prices change before and after E-ZPass adoption. Finally, we estimate models that include mother fixed effects in an effort to control for unobserved characteristics of mothers that could confound our estimates.

We find significant effects on infant health. The difference-in-difference models suggest that prematurity fell by 10.8% among mothers within 2km of a toll plaza, while the incidence of low birth weight fell by 11.8%. Importantly, the maternal fixed effects estimates are comparable. As one would expect, the estimated effects at 3km are smaller at 7.3% and 8.4% for prematurity and low birth weight respectively. These are large but not implausible effects given previous studies. In contrast, we find that there are no significant effects of E-ZPass adoption on the racial composition, fraction of teen mothers, or fraction of maternal smokers in the vicinity of a toll plaza. We also find no immediate effect on housing prices, suggesting that the composition of women giving birth near toll plazas shows little change in the immediate aftermath of E-ZPass adoption (though of course it might change more over time).

These results are robust to many changes in specification including adding Census tract fixed effects, restricting the "control" group to women within 10km of a toll plaza, excluding women with either very high or very low probabilities of living near a toll plaza, and estimating models excluding African-American mothers (who tend to have much more negative birth outcomes on average).

The rest of the paper is laid out as follows: Section I provides necessary background. Section II describes our methods, while data are described in Section III. Section IV presents our results, and Section V details our conclusions.

I. Background

Many studies suggest an association between air pollution and fetal health.[1] Mattison et al. (2003) and Glinianaia et al. (2004) summarize much of the literature. For more recent papers see for example Currie et al. (2009); Dugandzic et al. (2006); Huynh et al. (2006); Karr et al. (2009); Lee et al. (2008); Leem et al. (2006); Liu et al. (2007); Parker et al. (2005); Salam et al. (2005); Ritz et al. (2006); Wilhelm and Ritz (2005); Woodruff et al. (2008). Since traffic is a major contributor to air pollution, several studies have focused specifically on the effects of exposure to motor vehicle exhaust (see Wilhelm and Ritz (2003); Ponce et al. (2005); Brauer et al. (2008); Slama et al. (2007); Beatty and Shimshack (2009); Knittel, Miller, and Sanders (2009)).

At the same time, researchers have documented many differences between people who are exposed to high volumes of traffic and others (Gunier et al, 2003). A correlational study cannot demonstrate that the effect of pollution is causal. Women living close to busy roadways are more likely to have other characteristics that are linked to poor pregnancy outcomes such as lower income, education, and probabilities of being married, and a higher probability of being a teen mother. This is partly because wealthier people are more likely to move away from pollution. Depro and Timmins (2008) show that gains in wealth from appreciating housing values during the 1990s allowed households in San Francisco to move to cleaner areas. Banzhaf and Walsh (2008) show that neighborhoods experiencing improvements in environmental quality tend to gain population while the converse is also true.

Most previous studies include a minimal set of controls for potential confounders. Families with higher incomes or greater preferences for cleaner air may be more likely to sort into neighborhoods with better air quality. These families are also likely to provide other

[1] There is also a large literature linking air pollution and child and health, some of it focusing on the effects of traffic on child health. See Schwartz (2004) and Glinianaia et al. (2004b) for reviews.

investments in their children, so that fetuses exposed to lower levels of pollution also receive more family inputs, such as better quality prenatal care or less maternal stress. If these factors are unaccounted for, then the estimated effects of pollution may be biased upwards. Alternatively, emission sources tend to be located in urban areas, and individuals in urban areas may be more educated and have better access to health care, factors that may improve health. Omitting these factors would lead to a downward bias in the estimated effects of pollution, suggesting that the overall direction of bias from confounding is unclear.

Several previous studies are especially relevant to our work because they address the problem of omitted confounders by focusing on "natural experiments." Chay and Greenstone [2003a,b] examine the implementation of the Clean Air Act of 1970 and the recession of the early 1980s. Both events induced sharper reductions in particulates in some counties than in others, and they use this exogenous variation in pollution at the county-year level to identify its effects. They estimate that a one unit decline in particulates caused by the implementation of the Clean Air Act (or by recession) led to between five and eight (four and seven) fewer infant deaths per 100,000 live births. They also find some evidence that declines in Total Suspended Particles (TSPs) led to reductions in the incidence of low birth weight. However, the levels of particulates studied by Chay and Greenstone are much higher than those prevalent today; for example, PM10 levels have fallen by nearly 50 percent from 1980 to 2000. Furthermore, only TSPs were measured during the time period they examine, which precludes the examination of other pollutants that are found in motor vehicle exhaust.

Other studies that are similar in spirit include a sequence of papers by Pope and his collaborators, who investigated the health effects of the temporary closing of a Utah steel mill (Pope, 1989; Ransom and Pope, 1992; Pope, Schwartz, and Ransom, 1992) and Friedman et al.

(2001) who examine the effect of changes in traffic patterns in Atlanta due to the 1996 Olympic games. However, these studies did not look at fetal health. Parker et al. (2008) examine the effect of the Utah steel mill closure on preterm births and find that exposure to pollution from the mill increased the probability of preterm birth. This study however does not speak to the issue of effects of traffic congestion on infant health.

E-ZPass is an electronic toll collection system that allows vehicles equipped with a special windshield-mounted tag to drive through designated toll lanes without stopping to manually pay a toll. The benefits include time saved, reduced fuel consumption, and reductions in harmful emissions caused by idling and acceleration at toll plazas. The congestion benefits are substantial, with some estimates suggesting an 85 percent reduction in toll plaza delays within the first year of E-ZPass adoption (New Jersey Turnpike Authority, 2001). In addition, the air quality benefits are large enough that some counties have introduced electronic toll collections explicitly in order to meet pollution migitation requirements under the Clean Air Act (Saka et al. 2000). Estimates of the reduction in pollution with E-ZPass adoption vary and depend on factors such as how many lanes are converted to electronic toll collection, how rapidly vehicles can proceed through the lanes and so on. Saka et al. (2000) find reductions of 11% for nitrogen oxide (NOx) and a decrease of more than 40% for hydrocarbons and carbon monoxide (CO). Venigalla and Krimmer (2007) study the George Washington Bridge toll plaza, one of those included in this study, and found reductions in emissions of volatile organic compounds from trucks of up to 50%. Lin and Yu (2008) report reductions of 58% in particulate matter from diesel exhaust. They point out that these reductions can occur without any change in traffic flows because much of the emissions occur during the final acceleration back to normal travel speed after a vehicle leaves the toll booth.

Currie, Neidell, and Schmeider (2008) examine the effects of several pollutants on fetal health using models that include maternal fixed effects to control for potential confounders. They find that CO is particularly implicated in negative birth outcomes. In pregnant women, exposure to CO reduces the availability of oxygen to be transported to the fetus. Carbon monoxide readily crosses the placenta and binds to fetal haemoglobin more readily than to maternal haemoglobin. It is cleared from fetal blood more slowly than from maternal blood, leading to concentrations that may be 10 to 15 percent higher in the fetus's blood than in the mother's. Indeed, much of the negative effect of smoking on infant health is believed to be due to the CO contained in cigarette smoke (World Health Organization, 2000). Hence, the significant documented effects of E-ZPass on CO alone could have a significant positive effect on fetal health.

An important unresolved question is how far elevated pollution levels extend from highways or toll plazas? Most studies have focused on areas 100 to 500 meters from a roadway. However, Hu et al (2009) find evidence that pollution from the 405 Freeway in Los Angeles is found up to 2,600 meters from the roadway. Moreover, their study was conducted in the hours before sunrise, when traffic volumes are relatively light, but most people are in their homes. These new data suggest that mothers up to 3 kilometers from a toll plaza could benefit from the implementation of E-ZPass. Hence, we start with this cutoff below, and then examine mothers in a narrower band around the toll plaza.

We focus on the implementation of E-ZPass on three major state tollways in New Jersey and Pennsylvania, the Pennsylvania Turnpike, the New Jersey Turnpike, and the Garden State Parkway. Portions of all three of these state highways rank nationally as some of the busiest in the country. In addition to these state tollways, we also use the major bridge and tunnel tolls connecting New Jersey to New York (George Washington Bridge, Lincoln Tunnel, and the Holland Tunnel). Each of these bridge and tunnels are extremely well traveled, transporting around 105 million, 42 million, and 35 million vehicles respectively. New Jersey has 38 toll plazas, 3 at bridge/tunnel entrances to New York City, 11 along the Garden State Parkway, 22 along the New Jersey Turnpike, and 2 along the Atlantic City Expressway. There are 60 toll plazas in Pennsylvania. Figure 1 shows the toll plazas and major highways that we used to make these distinctions.

Our research design exploits the fact that E-ZPass was installed at different times and in different locations across the two states. The Port Authority of New York and New Jersey implemented E-ZPass at the bridge and tunnels entering New York City in 1997. Soon after, New Jersey installed its first E-ZPass toll plazas on the Atlantic City Expressway. Starting in December 1999, New Jersey began installing E-ZPass on the Garden State Parkway. Throughout the course of the following year, toll plazas were added at the rate of 1 per month (working from North to South on the GSP), with the final plaza installed in August of 2000. In September 2000, the NJ Turnpike installed E-ZPass at all their toll collection terminals throughout the system. Similarly, the PA Turnpike installed most of their toll-plazas with E-ZPass in December 2000, with a major addition occurring in December of 2001. E-ZPass adoption and takeup was extremely rapid. By early 2001 (1 year after implementation of the Garden State Parkway and NJ Turnpike), 1.3 million cars had been registered with E-ZPass in New Jersey, and the estimated total annual savings in delay time was around 2.1 million hours just for the New Jersey Turnpike (according to the NJ Turnpike Authority annual newsletter (http://www.state.nj.us/turnpike/00arfull.pdf) and NJ Turnpike Authority, 2001).

II. Data

Our main source of data for this study are Vital Statistics Natality records from Pennsylvania for 1997 to 2002 and for New Jersey for the years 1994 to 2003. Vital Statistics records are a very rich source of data that cover all births in the two states. They have both detailed information about health at birth and background information about the mother, including race, education, and marital status. We were able to make use of a confidential version of the data with the mother's address, and we were also able to match births to the same mother over time using information about the mother's name, race, and birth date. Like most previous studies of infant health, we focus on two birth outcomes, prematurity (defined as gestation less than 38 weeks) and low birth weight (defined as birth weight less than 2500 grams). Outcomes such as infant deaths and congenital anomalies are much rarer, and when we restrict the data set to those who are within 3km of a toll plaza, there are insufficient cases in our data for us to be able to expect to see an effect.[2]

Using this information, we first divided mothers into three groups: Those living within 3km of a toll plaza; those living within 3km of a major highway, but more than 3km from a toll plaza; and those who lived 3km or more away from both a toll plaza or a major highway. Our treatment group in the difference-in-difference design is the mothers living within 3km of a toll plaza, while the control group is those who live close to a highway, but further than 3km away from a toll plaza. We drop mothers who live more than 3km away from a highway. We also drop births that occurred more than 3 years before or after the E-ZPass conversion of the nearest plaza, in an effort to focus on births that occurred around the changes. Finally, we dropped births to mothers who were pregnant at the time of the E-ZPass conversion in order to be able to

[2] There are approximately 440 deaths within 3km of a toll plaza before E-ZPass compared to 6695 premature births.

compare infants who were not exposed to the treatment to those who were exposed throughout their pregnancies. All of the mothers in the sample are assigned to their nearest toll plaza.

Figure 2 illustrates the way that we created the treatment and control groups. As one can see from the figure, there are many homes within the relevant radius of the toll plaza. Moreover, housing tends to follow the highway. The areas more than 3km away from either a toll plaza or the highway are somewhat less dense. We also repeat this procedure using mothers less than 2km from a toll plaza as the treatment group, comparing them to mothers who live within 3km of a highway but more than 2 km from a toll plaza. The idea is that pollution should have larger effects on those who are closer to the highway.

In the analysis including mother fixed effects, we select the sample differently. Specifically, we keep only mothers with more than one birth in our data. We then restrict the sample to only mothers who have had at least one child born within 2km of a toll plaza, since only these mothers can help to identify the effects of E-ZPass. We use all available years of sample data, in order to maximize the number of women we observe with two or more children.

We also obtained data on housing prices in New Jersey from 1989 to 2009 by submitting an open access records request. In addition to the sales date and price, these data include information about address, square footage, age of structures, whether the unit is a condominium, assessed value of the land, and assessed value of the structures. We will use these data to see if housing prices changed in the neighborhood of toll plazas in response to amenity benefits generated from reduced traffic congestion and increased air quality surrounding E-ZPass implementation.

Means of the outcomes we examine (prematurity and low birth weight) and of the independent variables are shown in Table 1 for all of these groups. Panel A shows means for the treatment and control group used in the difference-in-differences analysis. For the control group, "before" and "after" are assigned on the basis of when the closest toll plaza converted to E-ZPass. The last column of Panel A shows that mothers who live more than 3km from a major highway are quite different than the other mothers. They are less likely to have a premature birth, and their babies are less likely to be low birth weight. They are also less likely to be black or Hispanic, and less likely to be high school dropouts or teen mothers. These mothers are omitted from our difference-in-difference analysis as discussed above.

The treatment and control groups are reasonably similar to each other before the adoption of E-ZPass except in terms of racial composition: Mothers close to toll plazas are much more likely to be Hispanic and somewhat less likely to be African-American than other mothers. Mothers close to toll plazas are also less likely to have smoked during the pregnancy. These differences have potentially important implications for our analysis, since other things being equal, African Americans and smokers tend to have worse birth outcomes than others. These differences in composition could explain, for example, why we do not see elevated levels of low birth weight and prematurity in the neighborhood of toll plazas in the raw data. These differences will be controlled for in our analysis, and we also experiment with several alternative control groups.

In terms of before and after trends, both types of areas show increases in the fraction of births to Hispanic and African-American mothers, and decreases in the fraction of births to smokers and teen mothers over time. The fraction of births that were premature rose over time, especially in the control areas. The fraction of births that were low birth weight showed a slight decrease in the treatment area near toll plazas, but stayed constant in the control areas.

Appendix Table 1 shows that changes in mean outcomes are generally similar if we restrict the treatment group to those who were within 2km of a toll plaza. Unfortunately, we have few observations within one kilometer of a toll plaza, which makes it difficult to look for effects at a very small distance from the toll plazas. The last two columns of Panel A of Appendix Table 1 show "before" and after means using an alternative control group: the group that is less than 3km from a busy road, but between 2 and 10 km of a toll plaza. This restriction reduces the control sample size by more than 50%, but does not result in racial balance between the treatment and control samples. It does however, reduce the gap in mean smoking rates. Below we discuss various alternative means of choosing a control group and testing the robustness of our results.

Panel B of Table 1 shows means for the sample that we use in the mother fixed effects analysis. We divide mothers into those who ever had a birth within 2km of a toll plaza, and those who never had such a birth. Within each group, we then estimate means for births before and after E-ZPass to see, whether on average, there are changes in these groups of mothers over time.

Panel B shows that in general, the mothers with more than one birth in the sample have somewhat better birth outcomes—their children are less likely to be premature or low birth weight than in the full sample of children (Panel A). However, the sample of women who have more than one birth and who ever had a child within 2 km of a toll plaza changes over time. Comparing columns 1 and 2 shows that this population has become more likely to be Hispanic, more likely to be high school dropouts, and somewhat more likely to be having a higher order birth. They also live somewhat closer to a highway.   Columns 3 and 4 of Panel B show that the population of women who never had a birth within 2 km of a plaza are quite different—they are less likely to be Hispanic, the sample tends to gain education over time, and (not surprisingly) lives further from a highway.

Panel C shows means from the housing sales data. All prices were deflated by the CPI into 1993 dollars. Comparing columns 1 and 3 suggests that sales prices and assessed values were lower before E-ZPass adoption in areas close to toll plazas, but that prices converged after adoption. Also, housing units near toll plazas tend to be a little older and a little smaller than those further away.

III. Methods

For the difference-in-difference analysis, we limit the sample to mothers within 3km of a major highway and first examine the effect of E-ZPass on the characteristics of mothers who live near a toll plaza. These models take the following form:

$$(1)\ Mom\_Char_{it} = a + b_1 E\text{-}ZPass_{it} + b_2 Close_{it} + b_3 Plaza_{it} + b_4\, E\text{-}ZPass*Close_{it} + b_5 Close_{it}*Plaza_{it} + b_6 Year + b_7 Year*Plaza_{it} + b_8\, Month + b_9\, Distance_{it} + e_{it},$$

where Mom_Char_{it} are indicators for mother i's race or ethnicity, her education, teen motherhood, and whether she smoked during pregnancy t. *E-ZPass* is an indicator equal to one if the closest toll plaza has implemented E-ZPass, $Close_{it}$ is an indicator equal to one if the mother lived within 3km (or 2km) of a toll plaza, and $Plaza_{it}$ is a series of indicators for the toll plazas. The coefficient of interest is that on the interaction between $E\text{-}ZPass_{it}$ and $Close_{it}$. We include interactions between $Close_{it}$ and $Plaza_{it}$ to control for any systematic differences between areas close to a specific toll plaza compared to areas slightly further away. We also include indicators for the year and month, and allow for plaza specific time trends. Finally, we control for linear distance from a busy roadway. Standard errors are clustered at the level of the toll plaza, to allow for correlations in the errors of mothers around each plaza. If we saw that maternal characteristics changed in some systematic way following the introduction of E-ZPass, then we would need to take account of this selection when assessing the effects of E-ZPass on health outcomes.

We also estimate models of the effects of E-ZPass on housing prices. These models are similar to (1) above except that they control for the ratio of assessed structure to land values, an indicator for whether it is a condo, age (in categories, including missing), square footage (in categories, including missing), and year and month of sale.

We next estimate models of the effects of E-ZPass on the probabilities of low birth weight and prematurity. These models take the following form:

$$(2)\ Outcome_{it} = a + b_1 E\text{-}ZPass_{it} + b_2 Close_{it} + b_3 Plaza_{it} + b_4\, E\text{-}ZPass_{it}{*}Close_{it} + b_5 Close_{it}{*}Plaza_{it} + b_6 Year + b_7 Year{*}Plaza_{it} + b_8\, Month + b_9 X_{it} + b_{10}\, Distance_{it} + e_{it},$$

where *Outcome* is either prematurity or low birth weight, and the vector X_{it} of mother and child characteristics includes indicators for whether the mother is black or Hispanic; 4 mother education categories (<12, high school, some college, and college or more; missing is the left out category); mother age categories (19-24, 25-24, 35+); an indicator for smoking during pregnancy; indicators for birth order (2nd, 3rd, or 4th or higher order); an indicator for multiple birth; and an indicator for male child. Again, the main coefficient of interest is b_4 which can be interpreted as the difference-in-differences coefficient comparing births that are closer or further from a toll plaza, before and after adoption of E-ZPass.

As discussed above we estimate some models that define the treatment group as births to mothers who live within 3km of a toll plaza, and alternative models using mothers within 2km of a toll plaza. Since mothers who are closer should be exposed to higher concentrations of pollution, we expect to see larger effects in the closer group.

We also perform a series of robustness checks. First, we estimate models that include Census tract fixed effects, and models that omit maternal characteristics. If the estimated coefficients do not change very much, this would suggest that omitted variables are unlikely to be a concern. Second, we include interactions of $Close_{it}$ and a linear time trend. It is possible that areas close to toll plazas are generally evolving in some way that is different from other areas, but as we shall see, this does not seem to be the case. Third, we estimate models excluding people who live more than 10 km from a toll plaza. Fourth, we estimated models of the propensity to live close to a toll plaza to see whether mothers were more or less likely to live near a toll plaza before or after E-ZPass adoption. These models included all of the maternal and child characteristics listed above, zip code indicators, and interactions of these variables. We then excluded all observations with a propensity less than .1 or greater than .9 as suggested by Crump et al. (2009). Finally, we estimated models that that exclude African Americans since African Americans tend to have very different average birth outcomes than whites. As we show below, none of these changes in the basic specification affects our qualitative conclusions.

Models with mother fixed effects take the following form:

$$(3)\ Outcome_{it} = a_i + b_1 E\text{-}ZPass_{it} + b_2 Close_{it} + b_3 Plaza_{it} + b_4\, E\text{-}ZPass_{it} * Close_{it} + b_5 Close_{it} * Plaza_{it} + b_6 Year + b_7 Year * Plaza_{it} + b_8\, Month + b_9 Z_{it} + b_{10}\, Distance_{it} + e_{it},$$

where a_i is a fixed effect for each mother i, and Z is a vector including child gender and birth order and potentially time varying maternal characteristics including mother's age, education, and an indicator for smoking. Although all the mothers are selected to have had at least one child while residing within 2km of a toll plaza, we alternatively define the indicator for *Close* either as less than 2km from a toll plaza, or as less than 3km from a toll plaza.

IV. Results

Table 2 shows the results of estimating equation (1), the effects of E-ZPass on the characteristics of mothers who live near toll plazas and on housing prices. Each coefficient represents an estimate of b_4 from a separate regression. None of the maternal characteristics show any significant changes with E-ZPass adoption. Similarly, there is no immediate effect on housing prices, suggesting that it takes time for any effects through the housing market to be felt. These results suggest that the estimated health effects of E-ZPass are not due to changes in the composition of mothers who live close to toll plazas.

Table 3 shows our estimates of (2). Again, each coefficient is an estimate of b_4 from a separate regression. The base specification of (2) is shown in columns 2 and 5. The first and fourth columns show estimates that omit the vector of maternal characteristics, while the third and sixth columns show estimates that include fixed effects for each Census tract. The coefficient estimates are remarkably similar across the three specifications. The estimates with Census tract fixed effects in the first panel suggest that E-ZPass reduced the probability of prematurity by .007 percentage points, a 7.29% reduction from the baseline of .096 shown in Table 1. This suggests that in the 60,446 births that we observe within 3km of a toll plaza after E-ZPass, 423 preterm births were averted. A similar calculation indicates that E-ZPass reduced the incidence of low birth weight by 8.43%, which means that in our sample 423 low birth weight births were averted (of course many of these births overlap since most preterm infants are low birth weight).

Panel 2 of Table 3 shows that the estimates are indeed higher for women within 2 km of a toll plaza, as predicted. The estimated coefficient of -.0104 in the model with Census tract fixed effects for prematurity represents a 10.83% reduction in prematurity among mothers within 2km of a toll plaza. The estimates for low birth weight suggest a reduction of 11.8% in the incidence of low birth weight. These are large but not implausible effects.

Table 4 shows the robustness checks described above for the models using the 2km control group. The first panel of Table 4 shows the effect of adding interactions between $Close_{it}$ and a linear time trend to the model. These interactions capture any differences in the evolution of areas near toll plazas and other areas (such as, perhaps, different trends in the housing markets). Given that we have already included year effects and a time trend for each toll plaza, this is asking a lot of the data. Table 4 shows that these additional interaction terms are never statistically significant, and that adding them has no impact on the estimated effects at 2km.

The second panel of Table 4 shows estimates from a sample that excludes mothers who live more than 10km from a toll plaza. As discussed above, this restriction reduces our sample size a great deal. Still the results are qualitatively similar to those discussed above, though standard errors are somewhat larger. The third panel of Table 4 shows results based on the propensity-score trimmed sample. The means for this sample are shown in Appendix Table 1. As the Appendix Table shows, imposing this restriction does result in somewhat more balanced treatment and control groups, although there are still more Hispanic mothers living near toll plazas than in the control group. The means foreshadow the results in Table 4. They show that while prematurity increased in the treatment area by .003, it increased by twice as much in the control area. Moreover, while low birth weight declined in the treatment areas by almost .004, it increased by .003 in the control area. Similarly, the regression estimates in Table 4 show that E-ZPass adoption reduced prematurity and low birth weight in the trimmed sample.

Panel 4 of Table 4 shows that we get very similar results if we estimate the model using only non-Hispanic whites. This shows that our results are not driven by differences in the racial composition of areas near toll plazas and other areas.

Table 5 shows estimates of (3) that include mother fixed effects. Panel A defines *Close* as less than 3km from a toll plaza while Panel B defines *Close* as less than 2km from a toll plaza. Since all mothers have at least one child while they are less than 2km from a toll plaza (by sample construction), the main difference between the two specifications lies in how children born when their mothers live between 2 and 3km from a toll plaza are treated.

Despite the difference in the way the sample is drawn, the results are remarkably similar to those discussed above. The estimates in Panel A suggest that E-ZPass reduced prematurity and low birth weight by .0090 and .0087 percentage points, respectively. Once again, the estimates in Panel B which use the 2km definition are even larger at .0124 and .0114 for prematurity and low birth weight respectively. Relative to the means in Table 1, the latter figures represent a 7.1% decline in the incidence of prematurity and a low birth weight.

V. Conclusions

We provide the first estimates of the effect of improvements in traffic congestion on infant health. We show that E-ZPass reduced the incidence of prematurity and low birth weight in the vicinity of toll plazas by 10.83% and 11.8% respectively. These are large but not implausible effects given the correlations between proximity to traffic and birth outcomes found in previous studies. For example, Brauer et al. (2008) report an 11% increase in the probability of low birth weight in Vancouver mothers who lived within 50 meters of a busy roadway compared to other mothers. Slama et al. (2007) measure levels of PM2.5 (particulates less than 2.5 microns in diameter) associated with traffic and find that mothers in the highest quartile of exposure had a risk of birth weight less than 3000 grams that was 1.7 times higher than mothers in the lowest quartile of exposure. Ritz and Williams (2003) find that the risk of preterm birth was 8% higher in mothers in the highest quartile of a distance weighted traffic exposure measure, an estimate that is remarkably similar to our own.

The strength of our approach is that our estimates are based on a credible natural experiment rather than correlations between proximity and outcomes. Importantly, our results are robust across a variety of specifications, providing reassuring evidence on the credibility of the research design. A weakness is that we do not directly observe the reductions in pollution that took place due to E-ZPass. However, as discussed above, engineering studies at individual plazas strongly suggest that E-ZPass resulted in 85% reductions in traffic delays and up to 50% reductions of emissions of harmful pollutants including CO, VOCs, and particulate matter.

Our results suggest that policies intended to curb traffic congestion can have significant health benefits for local populations in addition to the more often cited benefits in terms of reducing travel costs. Traffic congestion is an increasingly salient issue, with annual congestion delays experienced by the average peak-period driver increasing 250% over the last 25 years. In 2007, congestion cost about $87.2 billion in a study of 439 U.S. urban areas in terms of wasted time and fuel (Schrank and Lomax, 2009). Our results suggest that these numbers are lower bounds to the true costs, since the health externalities of traffic congestion contribute significantly to social costs.

The recent Institute of Medicine report on the costs of prematurity estimated that the societal cost was $51,600 per infant (in 2005 dollars, Behrman and Butler, 2007). Hence, the 10.8 percent reduction in the risk of prematurity (from a risk of roughly 10%) in the 138,315 infants born within 2km of a toll plaza in the 3 years after the implementation of E-ZPass can be valued at approximately $77 million. While it is difficult to know precisely how many of the roughly 4 million infants born each year in the U.S. are affected by traffic congestion, estimates from the American Housing Survey (2003) suggest that 26% of occupied units suffer from street noise or other disamenities due to traffic; hence, roughly 1 million infants are potentially affected. This figure suggests that nationwide reductions in prenatal exposure to traffic congestion could reduce preterm births by as many as 10,800 annually, a reduction that can be valued at $557 million per year. Since we have focused on only one of the possible health effects of traffic congestion, albeit an important one, the total health benefits of reducing pollution due to traffic congestion are likely to be much greater.

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Figure 1: Location of Interstates, Major Highways, and Electronic Tolls in New Jersey and Pennsylvania

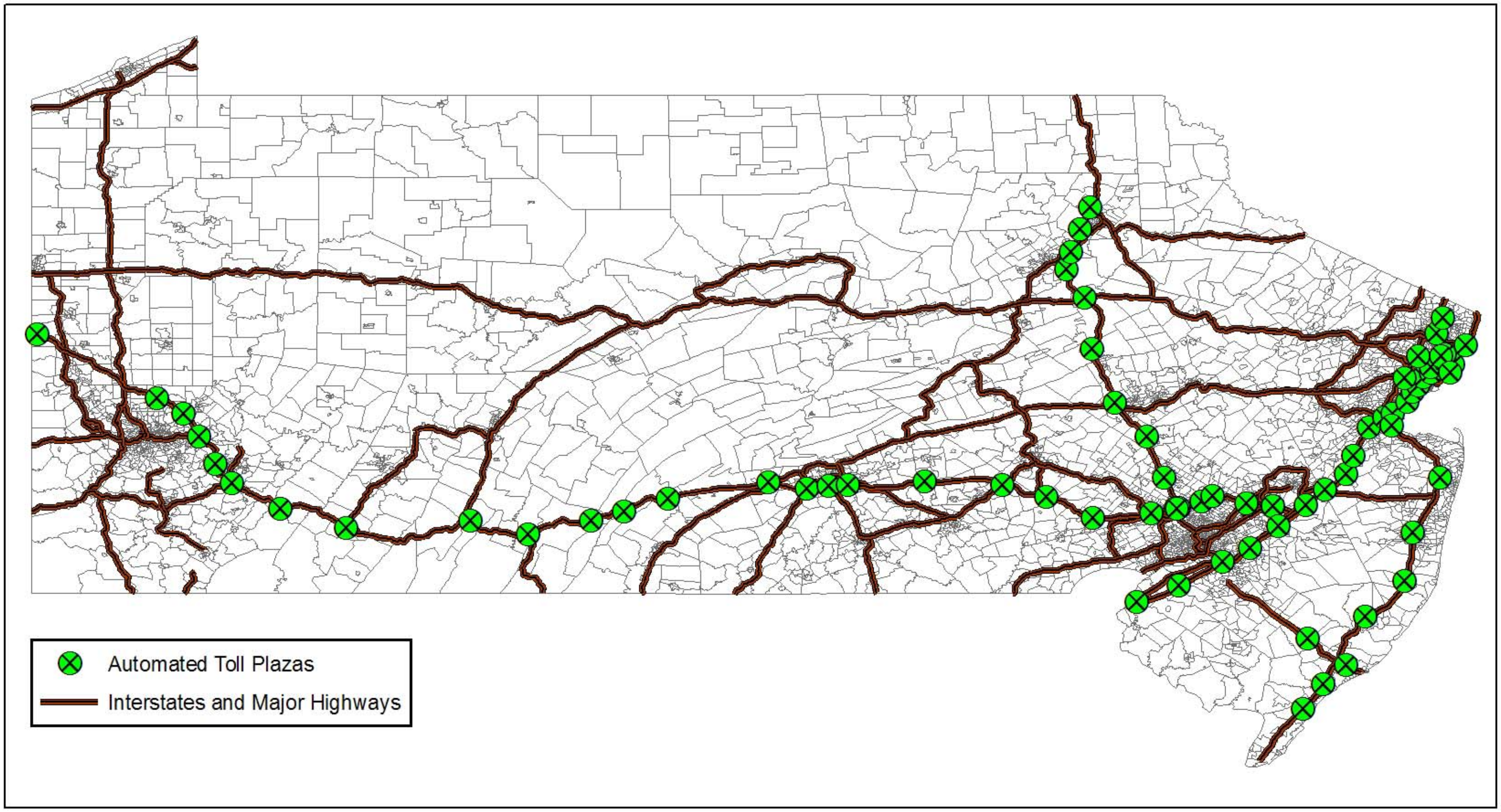

Figure 2: Visual Depiction of Treatment and Control Design

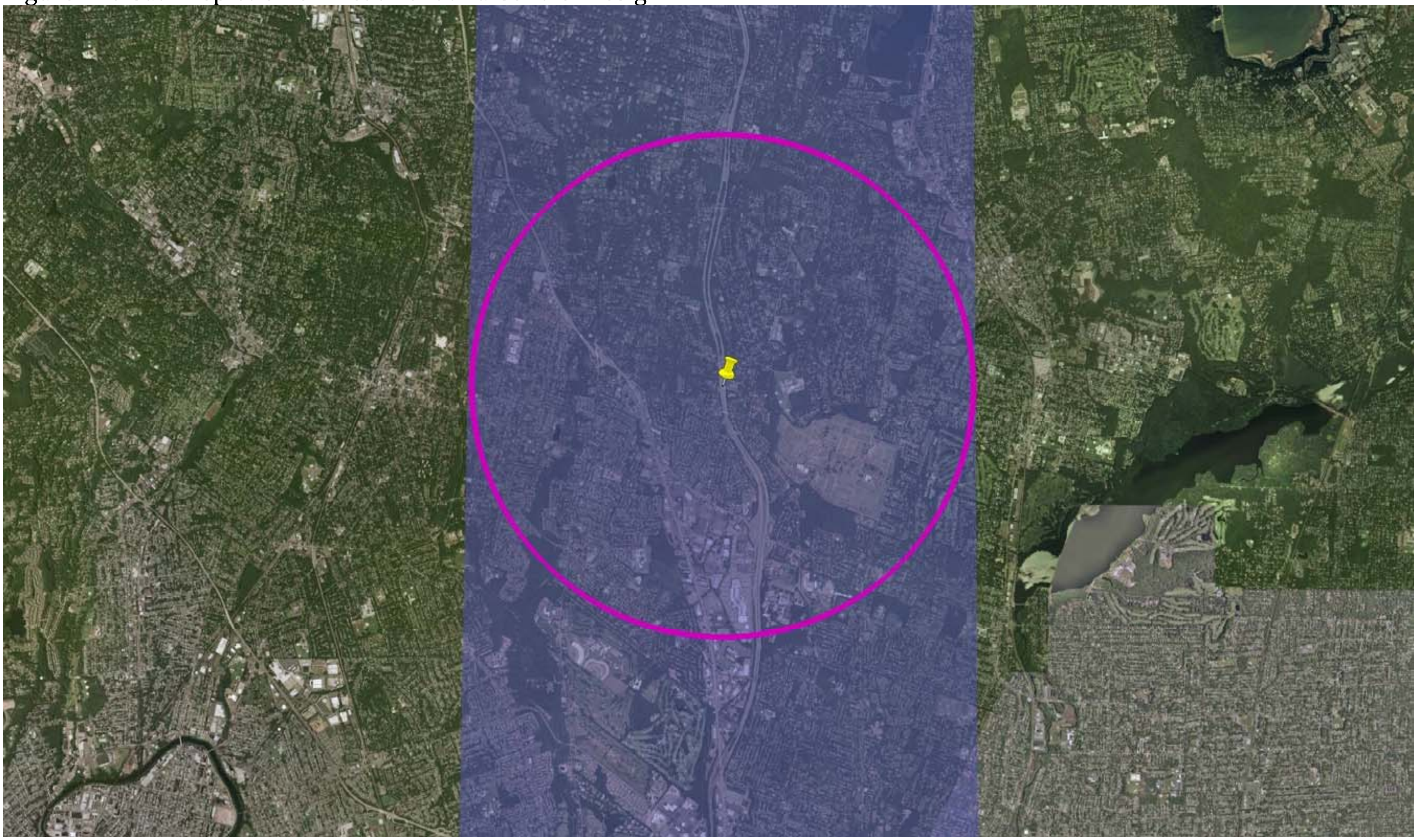

Table 1: Summary Statistics

Panel A: Difference-in-Difference Sample

Outcomes	**<3km E-Zpass Before**	**<3km E-Zpass After**	**>3km E-Zpass Before**	**>3km E-Zpass After**	**>3Km Highway**
Premature	0.096	0.099	0.102	0.108	0.091
Low Birth Weight	0.083	0.081	0.096	0.096	0.083
Controls					
Mother Hispanic	0.252	0.297	0.117	0.174	0.09
Mother Black	0.167	0.185	0.229	0.242	0.109
Mother Education	13.21	13.28	13.24	13.34	13.45
Mother HS Dropout	0.157	0.156	0.163	0.161	0.133
Mother Smoked	0.09	0.076	0.134	0.101	0.134
Teen Mother	0.069	0.058	0.102	0.082	0.074
Birth Order	1.31	1.378	1.528	1.547	1.644
Multiple Birth	0.0303	0.0347	0.032	0.0381	0.0352
Child Male	0.512	0.514	0.513	0.511	0.512
Distance to Roadway	1.349	1.417	1.488	1.476	.
Housing Prices (NJ)	92,745	133,487	108,226	131,358	118,783
Number of Obs.	69,742	60,446	364,473	245,909	829,542
New Jersey Obs.	53,157	53,355	140,621	147,060	370,327
Penn. Obs	16,585	7,091	223,852	98,849	459,215

Panel B: Mothers with More than One Birth in Sample

Outcomes	**Ever Birth<2km E-Zpass Plaza Before**	**Ever Birth<2km E-Zpass Plaza After**	**Never Birth<2km E-Zpass Plaza Before**	**Never Birth<2km E-Zpass Plaza After**
Premature	0.088	0.099	0.092	0.103
Low Birth Weight	0.081	0.077	0.086	0.086
Controls				
Mother Hispanic	0.167	0.29	0.088	0.161
Mother Black	0.145	0.157	0.169	0.171
Mother Education	12.78	12.6	12.75	13.13
Mother HS Dropout	0.168	0.201	0.178	0.162
Mother Smoked	0.113	0.076	0.135	0.095
Teen Mother	0.041	0.044	0.072	0.047
Birth Order	1.575	1.708	1.598	1.735
Multiple Birth	0.03	0.037	0.033	0.046
Child Male	0.513	0.512	0.512	0.512
Distance to Highway	3.702	2.561	5.598	5.3
Total # Obs.	179,537	58,180	1,640,118	485,351
NJ Obs.	85,565	47,012	678,025	352,751
PA Obs.	93,972	11,168	962,093	132,600

Panel C: Summary Statistics for Housing Sales Data (New Jersey Only)

	<2km E-Zpass Before	**<2km E-Zpass After**	**>2km E-Zpass Before**	**>2km E-Zpass After**
Sales Price	82,262	133,414	102,578	131,382
Assessed Land Value	45,555	49,450	58,769	65,699
Assessed Building Value	72,654	84,164	82,514	89,275
Total Assessed Value	116,671	132,323	140,482	154,584
Year Built	1,948	1,945	1,953	1,952
Square Footage	1,613	1,643	1,708	1,705
# Obs.	9,684	7,099	183,569	98,660

Notes: All observations in Panel A are selected to be within 3km of a busy roadway. The housing price data is only for New Jersey and pertains to housing units, not mothers, as described in the text. The housing price data has been deflated by the CPI (base year=1993)

Table 2: "Placebo Regressions" of Maternal Characteristics on E-Zpass Adoption
Difference in Difference Specification

	[1]	[2]	[3]	[4]	[5]	[6]	[7]
Panel 1	**Black**	**Hispanic**	**Mother Yrs. Ed**	**Dropout**	**Teen Mother**	**Mother Smoked**	**Housing Sale Price**
<3km toll*after E-Zpass	-0.202	0.035	-0.297	0.0003	-0.002	0.276	0.0635
	[0.250]	[0.242]	[0.303]	[0.002]	[0.003]	[0.334]	[01280]
R-squared	0.018	0.028	0.021	0.071	0.033	0.034	0.076
Panel 2							
<2km toll*after E-Zpass	-0.139	0.1698	-0.299	-0.006	-0.003	0.503	0.1377
	[0.378]	[0.4288]	[0.432]	[0.005]	[0.004]	[0.535]	[.1277]
R-squared	0.018	0.031	0.022	0.066	0.031	0.037	0.076

Notes: There are 740,801 observations in columns 1-6 and 325,095 in column 7. The table shows the indicated coefficient from regressions that also included controls for being within 3km (or 2km) of a toll plaza, year of birth, month of birth, indicators for each toll plaza, an indicator for post E-Zpass at nearest toll plaza, linear time trends for each toll plaza, and distance to highway. Housing sale price regressions included year and month of sale rather than of birth, the ratio of assessed structure to land values, an indicator for condos, square footage (in categories including dummies for missing), and age (in categories, including dummies for missing). Each coefficient is from a different regression. Standard errors in brackets.

Table 3: Regressions of Birth Outcomes on E-Zpass Adoption
Difference in Difference Specification

Panel 1	**[1] Prematurity**	**[2] Prematurity**	**[3] Prematurity**	**[4] LBW**	**[5] LBW**	**[6] LBW**
<3km toll*after E-Zpass	-0.0064	-0.0063	-0.0071	-0.0069	-0.0064	-0.007
	[0.0022]***	[0.0021]***	[0.0021]***	[0.0023]***	[0.0023]***	[0.0023]**
R-squared	0.0036	0.0254	0.0298	0.0062	0.0161	0.0213
Panel 2						
<2km toll*after E-Zpass	-0.0097	-0.0097	-0.0104	-0.0099	-0.0093	-0.0098
	[0.0039]**	[0.0038]**	[0.0038]***	[0.0031]***	[0.0031]***	[0.0031]***
R-squared	0.0033	0.0252	0.0299	0.0059	0.0159	0.0213
Maternal Characteristics	no	yes	yes	no	yes	yes
Census Tract FE	no	no	yes	no	no	yes
# Obs.	727,954	727,954	727,954	733,819	733,819	733,819

Notes: Each coefficient is from a different regression. All regressions also included controls for being within 3km (or 2km) of a toll plaza, year of birth, month of birth, toll plaza indicators, an indicator for post E-Zpass, linear time trends for each toll plaza, and distance to highway. Maternal characteristics include: mother black, mother hispanic, mother education (<hs, hs, some college, college +), mother age (19-24, 25-34, 35+), smoking, multiple birth, gender, and birth order. Standard errors in brackets. A *** indicates that the estimate is statistically significant at the 99% level of confidence. A ** indicates that the estimate is statistically significant at the 95% level of confidence.

Table 4: Robustness Checks, Birth Outcomes on E-Zpass Adoption
Difference in Difference Specification

	[1]	[2]
Panel 1: Add "close" x trend	**Prematurity**	**LBW**
<2km toll*after E-Zpass	-0.118	0.0088
	[0.0045]**	[0.0047]*
<2km E-Zpass*trend	0.0014	0.0007
	[0.0010]	[0.0013]
R-squared	0.0119	0.0154
# Obs.	740,570	733,602
Panel 2: Delete Controls >10km from a Toll Plaza		
<2km toll*after E-Zpass	-0.0067	-0.0073
	[.0039]*	[.0034]**
R-squared	0.0307	0.0126
# Obs.	405,598	409,465
Panel 3: Propensity Trimmed, .1<=P(x)<=.9		
<2km toll*after E-Zpass	-0.0075	-0.0076
	[0.0044]*	[0.0040]*
R-squared	0.0207	0.0105
# Obs.	123,776	124,984
Panel 4: Non-African Americans Only		
<2km toll*after E-Zpass	-0.0074	-0.0063
	[0.0037]**	[0.0028]**
R-squared	0.0233	0.0135
# Obs.	566,813	571,448
Panel 5: Non-Smokers Only		
<2km toll*after E-Zpass	-0.0096	-0.0085
	[0.0036]***	[0.0030]*
R-squared	0.0292	0.019
# Obs.	645,495	650,817

Notes: Each coefficient is from a different regression. All regressions also included controls for being within 3km (or 2km) of a toll plaza, year of birth, month of birth, toll plaza indicators, an indicator for post E-Zpass, linear time trends for each toll plaza, distance to highway, mother black, mother hispanic, mother education (<hs, hs, some college, college +), mothers age (19-24, 25-34, 35+), smoking, multiple birth, gender, and birth order. Standard errors in brackets. A ** indicates that the estimate is statistically significant at the 95% level of confidence. A * indicates significant at the 90% level.

Table 5: Mother Fixed Effects Estimates of the Effects of E-Zpass

Panel A	Prematurity	Low Birth Weight
<3km toll * after E-Zpass	-0.0090	-0.0087
	[0.0031]***	[0.0026]***
R-squared	0.195	0.193
Panel B		
<2km toll * after E-Zpass	-0.0124	-0.0114
	[0.0026]***	[0.0026]***
R-squared	0.0873	0.0936
#Obs	232,399	237,717

Notes: Each coefficient is from a different regression. All regressions also included controls for being within 3km (or 2km) of a toll plaza, year of birth, month of birth, an indicator for post E-Zpass,toll plaza indicators, toll plaza specific time trends and distance to highway. Maternal characteristics include: mother's age (19-24, 25-34, 35+), smoking, and mother's education (<12, 12, 13-15, 16+). Child gender and birth order are also controlled. Standard errors in brackets. A *** indicates that the estimate is statistically significant at the 99% level of confidence. A ** indicates that the estimate is statistically significant at

Appendix Table 1: Means for Alternative Samples

Panel A: Treatment, Control and Omitted Groups, Before and After E-Zpass

Outcomes	<2km E-Zpass Before	<2km E-Zpass After	>2km E-Zpass Before	>2km E-Zpass After	<10&>2km E-ZPass Before	<10&>2km E-ZPass After
Premature	0.0947	0.0952	0.101	0.107	0.102	0.109
Low Birth Weight	0.0825	0.0784	0.0945	0.0947	0.089	0.0922
Controls						
Mother Hispanic	0.29	0.332	0.125	0.184	0.165	0.229
Mother Black	0.16	0.174	0.224	0.237	0.233	0.264
Mother Education	13.12	13.2	13.25	13.34	13.27	13.24
Mother HS Dropout	0.169	0.165	0.162	0.159	0.154	0.163
Mother Smoked	0.0891	0.0755	0.13	0.0986	0.109	0.0855
Teen Mother	0.0728	0.061	0.0986	0.0792	0.082	0.0693
Birth Order	1.296	1.365	1.51	1.529	1.388	1.455
Multiple Birth	0.0282	0.0333	0.0321	0.0379	0.0316	0.0368
Child Male	0.51	0.512	0.513	0.512	0.514	0.512
Distance to Highway	1.098	1.073	1.496	1.484	1.507	1.482
Housing Prices (NJ)	91,256	138,315	106,014	130,489	93,426	119,063
Total # Obs.	33,684	29,577	400,531	276,778	190,882	161,119
# Obs.<1km E-Zpass	5,671	5,289	.	.	.	.

Panel B: Observations with .1>= P(close)>=.9 only

Outcomes	<3km E-Zpass Before	<3km E-Zpass After	>3km E-Zpass Before	>3km E-Zpass After
Premature	0.0938	0.0971	0.094	0.1
Low Birth Weight	0.0818	0.0783	0.081	0.0843
Controls				
Mother Hispanic	0.161	0.213	0.118	0.17
Mother Black	0.166	0.203	0.173	0.21
Mother Education	13.58	13.61	13.64	13.65
Mother HS Dropout	0.111	0.116	0.111	0.118
Mother Smoked	0.0956	0.0772	0.0988	0.0805
Teen Mother	0.0604	0.0484	0.0583	0.0515
Birth Order	1.392	1.437	1.418	1.454
Multiple Birth	0.0323	0.0357	0.0318	0.0368
Child Male	0.512	0.519	0.517	0.511
Distance to Roadway	1.254	1.214	0.1574	1.604
Number of Obs.	37,203	30,393	41,320	32,857

Note: all observations in Panels A and B are selected to be <3km from a highway.