One for the Road: Public Transportation, Alcohol Consumption, and Intoxicated Driving

April, 2009∗

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Abstract

We exploit arguably exogenous train schedule changes in Washington DC to investigate the relationship between public transportation provision, the risky decision to consume alcohol, and the criminal decision to engage in alcohol–impaired driving. Using a triple differences strategy, we find that that both DUI arrests and alcohol related fatal traffic accidents fell by as much as 40% with the service expansions. However, we also find evidence that each additional hour of late-night operation increased alcohol consumption, particularly in areas where alcohol venders are located close to Metro stations. Incorporating this moral hazard into our results suggests that each hour of public transportation available increased the number of heavy drinkers by 16% in neighborhoods with more than one bar within 100 meters of a Metro station. Consistent with these arrests results, we also find some evidence that fatal traffic accidents in the surrounding DC suburbs may have risen as public transportation expanded.

Keywords: Alcohol Consumption, Drunk Driving, Public Transportation
JEL classification: I18, R49

* * The authors wish to thank Stephanie Cellini, Matthew Freedman, Jordan Matsudaira, Christopher Carpenter, Jonah Rockoff, Timothy Moore, Alex Tabarrok, Sarah Bohn, and seminar participants at George Washington University, the 2009 ASSA meetings, and the 2009 IZA conference on the Economics of Risky Behavior for helpful comments, as well as Charlea Jackson of the Washington Metropolitan Police

Department for providing us with access to arrest data. Michael Shores provided valuable research assistance. All errors are our own.

I Introduction:

In 2005, nearly 1.4 million drivers were arrested for driving under the influence of alcohol or narcotics [Department of Justice (2005)] while there are 159 million self-reported episodes of alcohol–impaired driving among U.S. adults each year [Quinlan et al. (2005)]. During 2005, 16,885 people in the U.S. died in alcohol-related motor vehicle crashes, representing 31% of all traffic-related deaths [NHTSA (2006)] and it is estimated that alcohol-related crashes in the U.S. cost about $51 billion each year [Blincoe et al. (2002)].[1] The Center for Disease Control at the Department of Health and Human Services provides a variety of policy recommendations to reduce the incidence of alcohol-impaired driving[2] Virtually all these policies involve stricter laws, harsher penalties, and more aggressive enforcement to either increase the penalties associated with drinking while driving or decrease general alcohol consumption among youth. In this paper, we evaluate the impact of public policy aimed at reducing the probability that a drinker gets behind the wheel of a car.

It is a commonly held belief that the provision of accessible public transportation could reduce the incidence of DUIs. For example, the popular press regularly prints articles blaming high DUI incidence on the lack of public transportation.[3] Both public and private organizations provide transportation to drinkers in order to reduce DUIs – for example both the MillerCoors and Anheuser-Busch Brewing Companies provide free transportation on popular holidays to and from “member” bars. The slogan of a current Illinois campaign to reduce DUI incidence is "designate a driver - stay overnight - use public transportation."[4] However, there is very little evidence on the relationship between the provision of public transportation and drunk driving, and no studies present empirical quantitative evidence that providing public transportation would actually reduce the incidence of drunk driving. Credible evidence on the relationship between public transportation and DUI incidence is also important for understanding of the benefit of urban transit systems since recent research, based on commuting and congestion patterns,

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[1] http://www.cdc.gov/ncipc/factsheets/drving.htm
[2] The complete list is available on their website. See appendix for webpage.
[3] Marsha Dorgan (Oct 22, 2008) "CHP DUI checkpoint results" Napa Valley Register , Alan K. Category (Oct 2 2008) The Drunk Driving Situation in Los Angeles , Mutineer Magazine
[4] http://www.cyberdriveillinois.com/publications/pdf_publications/dsd_a1495.pdf

argues that fixed-rail transit may actually *reduce* social welfare [Winston and Maheshri (2007)].

The lack of credible evidence about the effect of public transportation on social outcomes is due, in large part, to the fact that alteration of public transportation, particularly fixed rail service, requires a huge investment in infrastructure. As a result, in recent history, areas have rarely changed from having no public transportation system to having one – in fact, Glasear et. al. (2008) argue that since New York City fixed-rail transportation has been unchanged for so long, the location of stops can by considered exogenous. With no variation in public transportation availability within a geographic area, one is forced to compare outcomes such as DUI incidence in areas with no public transportation like Los Angeles, to that of areas with public transportation such as New York – clearly this is not satisfactory.[5]

Fortunately, while relatively rare, in a few areas there were changes in the hours of public transportation operation that one could use to do a before and after comparison within the same geographic area.[6] In an effort to provide adults reliant on Metro transit the chance to stay at bars until 1:30 am when most bars close[7], in 1999 Washington D.C. Metro extended its hours of operation on Friday and Saturday nights from midnight to 1 am in the morning. In 2000 this was further extended to 2 am[8], and then 3 am in 2003. We show that this service expansion resulted in a 7% increase in the number of people riding the Metro in the evening. Because the changes in schedule allow us to observe the same geographic area on the same day of the week during the same time of day, both with and without public transportation availability, one can use the changes in hours of operation of fixed rail transportation in D.C. to conduct the first credible investigation into the relationship between public transportation provision and the incidence of alcohol–impaired driving. Since increased public transportation could also affect drinking

[5] Notable exceptions to this include Baum-Snow and Kahn (2005) who assembles a 30 year panel of data on 13 cities, which allows them to capture variation over time and place, as well as Baum-Snow and Kahn (2000) and Holzer, Quigley and Raphael (2003) who takes advantage of a physical expansion of fixed rail lines. All of these papers look at the effect on commuting behavior of workers, as opposed to public health and safety

[6] In addition to Washington, DC, Boston's Massachusetts Bay Transportation Authority and Austin's Capital Metro Authority introduced late night service with the last ten years.

[7]http://media.www.gwhatchet.com/media/storage/paper332/news/1999/09/20/News/Metro.Considers.Extending.Hours-16550.shtml

[8] http://billonglbt.blogspot.com/2007_07_01_archive.html

behaviors by making nightspots more easily accessible, we also investigate the relationship between public transportation provision and alcohol-related crimes.

We identify the effect using a difference in differences in differences approach - comparing the difference in outcomes between the late night (the time of day that the number of hours of Metro availability changed) on Friday and Saturday (the days for which there were schedule changes) and the early evening on Friday and Saturday to the difference in outcomes during the late night and in the early evening on Thursday evenings (when there were no schedule changes). Public transportation is associated with a substantial reduction in DUI arrests across DC, as much as 44%. There is substantial spatial heterogeneity in this effect. We find that in neighborhoods where bars are located within walking distance of a Metro station there was a 7% reduction, on average, in alcohol-impaired driving arrests for each additional hour of Metro availability after midnight. We also find evidence of moral hazard in the form of increased alcohol related arrests (our proxy for excessive alcohol consumption). In a parallel analysis, we find evidence that late night public transportation significantly reduced alcohol related traffic fatalities in DC, but had only small effects on alcohol related fatalities in the Maryland and DC suburbs. While some of our estimated effects are somewhat imprecise, they are economically meaningful and paint a compelling and consistent picture.

The fact that alcohol related arrests and DUI arrests move in the opposite direction is compelling evidence that our effects are not driven by secular changes in overall crime.[9] Moreover, the fact that we find affect in both DUI arrests and alcohol related automobile accident is evidence that our effects are not driven by changes in police enforcement. As a further test of the validity of our identification strategy, we show that increased Metro availability has little effect on other crimes (non-DUI and non-alcohol-related). We also exploit the geographic variation in proximity to bars and Metro stations to test the validity of our strategy. We find that the reductions in DUI arrests and increase is alcohol-related arrests were larger in areas where there were more licensed alcohol venders, and in areas that were more Metro accessible. There were no such effects for non-alcohol related arrests. When the increase in potential drunk drivers is

[9] We cannot exclude reallocation of police resources away form drunk driving to what are by and large nuisance crimes, although given the high social cost, and high profile, of drunk driving this seems and unlikely policy decision.

taken into account, the *local* impact of public transportation on DUIs becomes quite large; we find that the ratio of DUI arrests to alcohol related arrests fell by 2.6% per hour of Metro service per “Metro accessible” bar, implying that even intoxicated individuals respond to incentives in a rational way. While our empirical results are somewhat imprecise, we present the first compelling evidence that cities can reduce DUI arrests by expanding public transportation availability, but we show that such expansion likely comes at the cost of a higher rate of alcohol consumption.

The remainder of the paper is as follows. Section II outlines the extant literature on alcohol consumption, crime and public transportation, section III presents the analytical framework describing how public transportation may affect drunk driving and drinking behaviors, section IV presents the empirical strategy, section V presents the results and section VI concludes.

II **Alcohol Consumption, Crime, and Public Transportation:**

The decision to drive while intoxicated is twofold: the *risky* decision to drink excessively and the *criminal* decision to drive home once inebriated. Economists have found that alcohol consumption can be reduced by increasing alcohol prices or taxes [Kenkel (1996); Chaloupka et al. (1993); Cook and Moore (1993),(2002); Kenkel and Manning (1996); and Leung and Phelps (1993)] enforcing minimum drinking age laws [Grossman and Saffer (1998); O’Malley and Wagenaar (1991)] and imposing harsher legal penalties on the frequency of alcohol consumption [Kenkel (1993)]. However, the extant literature has not evaluated policies aimed at reducing the social harm associated with alcohol use. We aim to fill this gap in the literature by investigating how the provision of public transportation reduces the rate at which alcohol consumption translates into socially costly DUI incidents.

Conditional on alcohol consumption, individuals evaluate the *criminal* decision to drive home once inebriated. As stated in Becker (1968) “a person commits a crime if the expected utility to him exceeds the utility he could get by using his time and other resources at other activities”.[10] Researchers have primarily focused on one side of this equation – reducing the prevalence of crime through policies intended to increase the

[10]See Doob and Webster (2003) and Levitt (2002) for reviews of the literature on risky behavior and deterrence.

expected *private* costs of illicit behavior.[11] However, since decisions to commit a crime are also a function of the opportunity cost of illicit behavior, crime could theoretically be reduced by increasing the private benefit of not committing a crime. We will refer to this mechanism as the "safer option" hypothesis.

There is some suggestive evidence that this third method may be effective. For example, Stevenson and Wolfers (2006) find that the introduction of unilateral divorce, which decreased the cost of ending a partnership, lead to a 30 percent decline in domestic violence for both men and women, and a 10 percent decline in females murdered by their partners. Since part of this effect is likely due to endogenous behavioral changes that take place as a result of the law, this is merely suggestive of the safer option hypothesis. Other suggestive evidence is a documented relationship between crime and poor labor market opportunities [Machin and Meghir (2004); Corman and Mocan (2000)], suggesting that increasing the return to labor force participation may induce people to substitute legitimate work for criminal behavior. Since unemployment and joblessness are also associated with depression [Lee et al. (1990] and other social dysfunction [Stankunas and Kalediene (2005)], and since crime may not simply be an income generating endeavor, it is not clear that the safe option effect is driving the results.

This safe option approach has rarely been used in crime prevention, but it has been used in public health policy.[12] For example, providing needles to drug addicts and handing out free condoms to teenagers are predicated on the notions that people will be less likely to share needles if they have a limitless supply of fresh needles, and teenagers will be willing to have sexual intercourse with a condom if condoms are available. The provision of late public transportation is very similar in that it allows bar clientele a safe way to get home that does not involve driving while drunk, reducing the social harm associated with consuming alcohol without reducing the expected cost of drinking to the

[11] Economists have found that increases in the size of the police force lead to decreases in crime [Evans and Owens (2007); Levitt (1997) (2002); Klick and Tabarrok (2005); DiTella and Schargrodsky (2004); Corman and Mocan, 2000]. Corman and Mocan (2000) find that increases in arrest rates are associated with decreases in crime and Levitt and Kessler (1999) find that increases in sentence length are associated with decreases in crime that they attribute to deterrence. However, there are notable exceptions to this finding, including Raphael and Ludwig (2000) and McCrary and Lee (2007). In addition, criminologists and sociologists have questioned the basic assumptions of the Becker model; specifically that criminal behavior can be characterized as rational, meaning forward looking with accurate information about costs and benefits (Doob and Webster 2003).

[12] A notable exception is job training programs targeted to at-risk populations.

individual. We fill this gap in the crime literature by explicitly testing an important prediction of the notion that crime can be described as a rational decision. Specifically, we test whether policy makers can reduce a person's likelihood to engage in criminal behaviors by improving in their utility while not committing a crime.

Policies of this nature have been criticized on the grounds that providing less risky alternatives to certain externally costly actions (i.e. drunk driving) could hurt society overall by increasing the likelihood that persons engage in other undesirable behaviors (i.e. excessive drinking) [Boyum and Reuter (1996)]. These policies may introduce a moral hazard – by providing a safer way to engage in socially undesirable behaviors, one makes socially undesirable behavior more attractive to individuals who do not internalize the full social costs of their actions [Pauly (1974); Holstrom (1979)]. In fact, in severe cases, such well-intentioned solutions could cause more harm than good [Hansen and Imrohorglu (1992)]. There is empirical support for this concern. Researchers have linked provision of the contraceptive pill to increased transmission of sexual diseases [Durrance (2007)], abortion availability to increased sexual activity [Klick and Stratmann (2003)] and improvements in the treatment of AIDS/HIV to risky sexual behavior in HIV positive individuals [Sood and Goldman (2006)].

Our paper is closely related to this literature since we look not only at how the availability of late transportation affects DWI arrests, but also its potentially deleterious effects on alcohol consumption. Indeed, alcohol consumption has been shown to be very responsive to price changes [Chaloupka et al. 2002]. Because the first order impact of this policy change can be interpreted as reducing the cost of drinking, *a-priori* we would expect alcohol consumption to increase as Metro service expands. There is a large and growing literature on the relationship between alcohol consumption and crime [Markowitz and Grossman (2000); Joksch and Jones (1993); Carpenter (2008); Dobkin and Carpenter (2008); Cook and Moore (1993)]. Approximately 40% of individuals under criminal justice supervision report being under the influence of alcohol at the time of offense [Greenfeld (1998)], and alcohol is notably the only mood altering substance shown to increase violent behavior in a laboratory setting [Boyum and Keiman (2002)]. As such, while we do not observe actual alcohol consumption, we are able to observe alcohol related arrests, which should serve as a good indicator for excessive drinking behaviors.

Concerns about a moral hazard effect are particularly salient for public transportation policy. Reducing the incidence of intoxicated driving would provide a benefit to society, but if public transportation substantially increases alcohol consumption, on net this may be a social loss. In addition, since drinking is a social activity [Boisjoly et al. 2003, Norton et al.(1998)], the reduced costs of alcohol consumption could result in an increase in the number of DUIs, even if the policy reduces the propensity of a given drinker to drive drunk.

III Analytic Framework

The first order policy relevant question is whether expanded access to public transportation reduces the incidence of intoxicated driving. Additional interesting questions are whether the availability of the Metro makes individuals more likely to consume alcohol, and if expanded access to public transportation makes it less likely that a given drinker will drive. In this section we present a simple model that links alcohol consumption and intoxicated driving to public transportation, then provide some intuition for the possible moral hazard created by Metro's expanded late night service.

A simple coordination game, combined with basic consumer demand and production theory can be used to analyze the potential effects of the expanded Metro hours of operation on DUI behaviors and on drinking behaviors.

The consumer problem: Individuals have demand for a good N, a night out, with price C_N, and a numerair good Y with price 1. Individual *i*'s utility from going out is an increasing function of aggregate going out for others in the population $\theta_{i'}$, so such that individual *i*'s utility is given by

$$U_i = f_i(g(N,\theta_{i'}),Y) \quad \text{where the budget constraint is} \quad E_i = Y_i + N_i \cdot C_N \quad [1].$$

The aggregate going out for others in the population is $\theta_{i'} = \sum_{i' \neq i}^{I} N_{i'} - N_i$ and $\partial g / \partial \theta_{i'} > 0$.

This social parameter captures the fact that drinking is a social activity. The amount of alcohol you consume is believed to be a positive function of the amount of alcohol others around you are drinking, although the empirical literature on the subject is not deep [Cook and Moore (2000)]. Promotion of Metro's expanded hours enhanced public awareness of downtown alcohol venders. The Washington Post characterized the service change as targeted at bar patrons, and Metro's publicity campaign highlighted late night activities downtown.[13] Utility maximization level of the numereair good Y and night out is given by

$$\frac{\partial f_i / \partial Y_i}{\partial f_i / \partial N_i} = C_N \qquad [2]$$

So that individuals chose their desired level of nights out based on the shape of their own utility functions.

The production of nights out: A night out is produced by combining two inputs, drinking D and transportation T. There are two modes of transportation, driving a car T_1 and taking the train T_2. The price of driving a car is p_1, the price of taking the train is p_2 and the price of drinking is p_d. The total price of a night out for individual *i* is

$$C_N = D \cdot P_{Di} + T_1 \cdot P_1 + T_2 \cdot P_{2i} \ . \qquad [3]$$

Where P_{Di} is the individual *i*'s price of driving (determined by car ownership, the price of gas etc.) and P_{2i} is individual *i*'s price of public transportation (determined by Metro ticket prices, taxi rates, Metro availability, and Metro accessibility). When there is no public transportation available $P_{2i} = \infty \ \forall i$. The provision of transportation constitutes a *reduction* in the price of taking the train from infinity to P_{2i} such that $0 < P_{2i} < \infty$.

Prediction 1: As the price of taking the train falls, the demand for driving falls as long as modes of transportation are gross substitutes and they are both normal inputs.

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[13] The opening scene of the televised ad campaign showed a pair of Metro doors opening onto a crowded bar, and the words 'Metro Opens Doors to Late Night Fun" The commercial can be viewed at http://www.lmo.com/case_studies-change_behavior.html

Prediction 2: As the price of taking the train falls, the cost of a night out decreases so that demand for a night out goes up, as long as a night out is a normal good.

Prediction 3: As the price of taking the train falls, the cost of a night out decreases and the demand for drinking goes up as long as a night out is a normal input.

In Equilibrium

Prediction 4: Since going out for person i and going out for person i' are strategic complements, as the price of taking the train falls, individual demand for a night out goes up, so that aggregate demand for a night out goes up, which in turn, increases demand for a night out. In equilibrium, there is an increase in aggregate going out and an increase in aggregate drinking.

Prediction 5: In equilibrium, the effect on aggregate drinking while driving is ambiguous. While the number of individual who go out drinking will increase, the number of individuals who drive to go out may decrease so that there is a reduction in drunk driving. Alternatively, as the fraction of a bar's patrons using the Metro increases, the amount of alcohol consumed by any given bar patron's peers will rise. On the margin, this peer effect will increase alcohol consumption among those who use private transportation.[14] If there is a large enough increase in drinking among drivers, even if the number of drivers goes down, the number of drinkers who drive may increase. As such, the effect of the reduction in the price of the Metro is theoretically ambiguous.

III **Data**

The data used in this paper is drawn from four sources. The first order issue is to determine whether or not Metro's late night service was actually used by area residents. Unfortunately, the Washington Metropolitan Area Transit Authority (WMATA) does not

[14] The Becker (1968) model of criminal behavior implies that some fraction of the drinking population will optimally choose to drive home. Alternately, some drinkers would optimally have chosen to use public transportation, but because of peer effects underestimated the amount of alcohol they eventually consumed. Both optimal and suboptimal behavior would increase the number of DUIs.

measure late night readership directly; total system use is measured each day between opening and 9:30 am, 9:30 am to 3 pm, 3 pm to 7 pm, and 7 pm to close. We use daily ridership levels from 1995 to 2006 to establish the relationship between public transportation and alcohol related behavior engendered by the schedule changes. Specifically – we expect larger changes in DUIs and alcohol consumption during periods when we see increased ridership, and evidence of large changes in arrests without changes in ridership are likely to be cause by some other unobserved mechanism.

We measure the relationship between public transportation, alcohol consumption, and intoxicated driving using detailed arrest data from Washington DC's Metropolitan Police Department (MPD). The data set contains information on all arrests made between 1998 and 2007, and includes information on the primary charge, date and time of the arrest, as well as the location of arrest. We identify changes in the number of intoxicated drivers using arrests for DUIs (driving under the influence) and DWIs (driving while intoxicated). We also use these arrest records to measure changes in the number of people arrested for alcohol related offences. While all crimes are more likely to occur if the victim or offender has been drinking, we argue that certain types of offenses are more likely to be associated with excessive drinking than others [Carpenter (2008)]; specifically, we focus on crimes that we consider most likely to be committed by individuals with an otherwise low criminal propensity, but have engaged in excessive drinking. These offenses include urinating in public, obscene gestures, drinking in public, possession of open alcohol containers, or defacing a building, as well as crimes for which victims may have been at higher risk due to their own excessive drinking (e.g. simple assault, unarmed robbery, rape, indecent exposure, indecent sexual proposal).[15]

Certain assumptions are required to make inferences about changes in criminal behavior using arrest data. While all officially reported crime statistics are based on the sub-sample of crimes that police officers are aware of, arrest records directly reflect police behavior in a way that official crime reports do not. A shift in police priorities from DUI arrests to disorderly conduct arrests, for example, could manifest itself in our data as a reduction in DUIs relative to arrests for other alcohol related crimes. In order for this to be a concern, it must be the case that this shift in priorities not only coincides with

[15] A list of arrests identified as "alcohol related" can be found in the Appendix.

the timing of Metro expansion, it *only* occurs on Friday and Saturday nights. We also must assume that the fraction of people arrested for disorderly behavior is a small fraction of the total population at risk, meaning that an increase in people arrested for disorderly behavior will have a negligible effect on the number of people who drive home drunk.[16]

Arrests for intoxicated driving make up 3% of all arrests in our sample period. Alcohol related crimes, by comparison, are approximated 34% of all recorded arrests.

< *figure 1* >

A few patterns are apparent in our data. First, as shown in figure 1, it is clear that there are many more DUI arrests on Friday and Saturday nights than any other day of the week. Looking at the arrest by hour, one can see that DUI arrests increase over time starting at 8pm and peak between 2am and 3am for all days except Friday and Saturday when they peak between 3am and 4am. Thursday night appears to be the most similar to Friday and Saturday night, which is perhaps not surprising given the large college and federal government employee population.[17] In comparison with DUIs, most arrests for alcohol related crimes occur around 10 pm, with a second local peak between 12 am, and 1 am, which would coincide with late night alcohol consumption (figure 2).

< *figure 2* >

In order to illustrate that our effects are working through the hypothesized channels, we show that these effects are largest in (a) areas with more drinking establishments and (b) areas where drinking establishments are more Metro accessible.[18] To take advantage of the hypothesized spatial variation in patterns of drinking and criminal behavior, we divide DC into neighborhoods based on Police Service Areas (PSAs). Some advantages of dividing DC into PSAs are worth noting. First, PSA are typically patrolled by the same group of officers, meaning that police officer arresting

[16]The probability of being arrested for driving 10 miles with a blood alcohol content of 0.1 has been estimated to be 0.15% (Beital et al. 2000). We are unaware of any estimates of the probability of arrest for minor offenses such as public intoxication, but this assumption seems reasonable. A very small fraction of the general offending population is apprehended; with clearance rates for non-violent offenses roughly 15% in 2006 (see the Sourcebook of Criminal Justice Statistics). Because of differences in the timing of when most DUIs and most Drunk and Disorderly arrests occur (see figure 1) it also is reasonable to assume that changes in police patrol that increase the p_d would also increase p_c.

[17] In 2008, the acting Director of the Office of Personnel Management estimated that roughly half of all federal civilian employees work an alternate work schedule in which ever other Friday is "off." http://www.govexec.com/pdfs/090308b1.pdf

[18] Note that it is possible (and perhaps common) for bar patrons to hire taxi cabs from Metro stations to distant bars, which contaminates our assumed linear relationship between distance and accessibility. This "taxi effect" will bias our estimates of Metro access towards zero.

behavior is likely to be correlated within, rather than across, PSAs. In addition, PSAs are relatively large, a topic of some concern when the boundaries were established,[19] making the assumption that someone arrested for a DUI was drinking in the PSA somewhat tenable, although far from perfect. Finally, PSA boundaries are designed to correspond with generally established neighborhood borders, so the composition of the population is relatively homogenous within a PSA.

When examining arrest data, we divide our sample into four time periods corresponding to the different Metro schedules. Each day is parsed into three time blocks: 5 am to 6 pm (day time), 6 pm to 10 pm (early evening), and 10 pm to 5 am (late evening). This allows us to differentiate between arrests occurring in the early evening, when Metro was always available and arrests occurring later in the evening, which we cannot do with the Metro ridership data. Note that in our data Friday night technically ends at 5 am on Saturday morning. During each Metro schedule, we then alternately collapse all arrests occurring within a day of the week–time block and PSA-day of the week-time block. This leaves us with two data sets- one where the unit of observation is a day of the week-time block-schedule (e.g.: Friday late nights during schedule 2) and one where the unit of observations is PSA-day of the week-time block-schedule (e.g.: Friday late nights during schedule 2 in PSA 305).

There are four advantages to aggregating the data in this way. Conceptually, we do not expect that arrests for DUIs and alcohol related arrests will be occurring during the same hour. Instead, it is more consistent to assume an increase in alcohol consumption will result in increased arrests throughout the evening, which only at the end of the night are DUIs. In addition, arrests (and particularly arrests for DUIs) are infrequent events. We want to estimate how the *size* of a population changes over time, and aggregating the data across for example, all Friday nights in a time period, allows us to estimate how this size changes based on repeated samples (arrests) from the population. While we lose power with this approach, the interpretation of the point estimate is more meaningful. Finally, while arrests for alcohol related offenses are likely to occur where the individual was drinking, this is less likely to be the case for DUI arrests. We therefore expect that

[19] See FAQs about PSA boundaries: http://mpdc.dc.gov/mpdc/cwp/view,a,1239,q,543455.asp

the number of DUI arrests within a given PSA to be a noisy signal of the number of DUI arrests resulting from drinking within that PSA and include a DC level analysis.

It is important to note that while it may be tempting to rely on the sharp changes in the hours of operation by comparing arrests right before the Metro is open to those right after the Metro is open, such an approach would be misguided. Since people are forward looking, it is clear that their drinking and driving behaviors are made in anticipation of Metro service (i.e. people leave their cars at home when they leave for the bars at 10pm because the Metro now runs till 2am. People may drink more at 11 pm because they know they can stay out longer now that the Metro is open later). These examples point out that to detect the full effect of the change requires that we use a relatively large time window. Using a large time window also has the added benefit of being much less susceptible to picking up shifting of crime across time. By defining the unit of observation to be the entire evening, we avoid measuring shifting of drinking or driving activity within an evening - and as such measure the true overall effect

< table 1 >

Table 1 provides summary statistics of average DUI and alcohol-related arrests occurring in each neighborhood during each Metro schedule by day of the week and time of day.. The numbers of DUI and alcohol-related arrests occurring in each PSA during the evening hours are highly correlated with each other (ρ=0.66). There is also a large amount of variation across neighborhood in the number of arrests; the standard errors for both DUI arrests and Alcohol related arrests are consistently larger than the mean values. Also note that as in the previous figures, unlike DUI arrests, most alcohol related arrests occur between 5 am and 6 pm, although there is a second spike during the late night hours on Friday and Saturday.

We identify the number of bars within each PSA using address information on establishments with a class CT alcohol license ("taverns") or general alcohol licenses provided by the DC Alcoholic Beverage Regulation Administration. Table 2 provides some sample statistics describing the number of alcohol licenses in each PSA. While this data are a stock of all existing licenses in 2008, most neighborhoods known for late night carousing, such as Adams Morgan (PSA 303) and Georgetown (PSA 206), have been under liquor license moratoriums since the late 1990s (District of Columbia Municipal

Regulations Title 23 Chapter 3). Two neighborhoods, U Street (PSA 305) and H Street (PSA 102), have large numbers of licenses in our database, due to highly visible neighborhood revitalization efforts in the early 2000s. Because information on alcohol venders in these two neighborhoods is functionally missing, we exclude these two PSAs from the part of our analysis dependent on the location and prevalence of alcohol vendors.[20] Figure 3 below shows the PSA boundaries for Washington D.C. along with the location of licensed alcohol venders (gray dots) and Metro Stations (blues squares). The PSAs in our sample have on average 30 alcohol venders in their borders (sd= 44.3). Only one neighborhood, PSA 702, does not contain any bars and 23 neighborhoods have at least one alcohol vender within 400 meters of a Metro station. We use the geographical variation in (a) the number of alcohol venders in a given PSA and (b) the accessibility of alcohol venders each PSA to a Metro station to see if those area that should be "more treated" by the change in Metro schedule based on *ex ante* characteristics actually experiencing larger treatment effects.

< figure 3 >

As a compliment to our arrest data, we use data from the Fatal Accident Reporting System (FARS) to test whether Metro service reduced traffic fatalities. This data set contains information on the date and time of all traffic fatalities occurring between 1994 and 2007, including a police assessment of whether or not alcohol was involved in the crash. We focus on traffic fatalities in the DC Metropolitan area. As shown in figure 3, the timing of traffic fatalities involving alcohol closely follows the pattern of DUI arrests. In contrast, non-alcohol related traffic fatalities (figure 4) are most likely to occur during the early evening, although when we aggregate the traffic fatality data in the same way that we aggregate the arrest data, we find a strong correlation between the number of alcohol and non-alcohol related fatalities (ρ=0.35).

< figure 4 >

While not all incidents of drunk driving will result in a fatal accident, this measure is not subject to the aforementioned changes in police reporting behavior.[21]

[20] Our empirical results are qualitatively identical if we include information from these two PSAs.

[21] In fact, while increases in policing could lead to an increase in DUI arrests, it would also lead to a reduction in fatal alcohol related automobile accidents. Since policing bias lead to biases of opposite sign for arrests and accident reductions in both measures of drunk driving would reflect real reductions in drunk driving.

IV Empirical Strategy

In principle there are two sources of variation in public transportation that can be exploited: (1) the temporal difference in provision by comparing outcomes when public transportation is provided to times when it is not; (2) the spatial variation by comparing outcomes in areas where there are many bars close to Metro stations to those of areas where Metro stations are not located near any bars.

When there is a set public transportation schedule (i.e. trains always run at 10 pm and never run at 5am), it is impossible to separate a time of day effect from a public transportation effect. For example, if the trains stop running at midnight, one might try to compare outcomes between 11 pm and midnight, to outcomes between midnight and 1 am. If the underlying outcomes (in the absence of any difference if public transportation availability) are the same between 11 pm and midnight and midnight and 1 am, this temporal comparison would yield the effect of public transportation availability on crime. However, this necessary precondition is unlikely since people are more likely to be drunk at 1 am then at 11 pm. Therefore, a comparison of outcomes across different times of day is unlikely to uncover a causal relationship. To avoid confounding time of day effects with Metro availability effects, one would want to compare the outcomes during the same time of day (and day of the week) when Metro was available to when Metro is not available.

The changes in the Metro schedule changed the times during which public transportation was provided – allowing one to compare outcomes during the same time of day (and day of the week) both with and without public transportation. Since the schedule changes break the perfect mutli-colinearity between hours of Metro availability and time of day for a given day of the week, we can control for time-of-day-by-day-of-week effects and use the change in the number of hours of Metro availability that occurs across the different schedules.

Using only the temporal variation, we can isolate the effect of changing Metro availability on Metro use, crime, and fatal accidents using a differences-in-difference-in-differences (DIDID) strategy. A simple difference strategy would only use data from

Friday and Saturday late nights and compare outcomes before and after the schedule change. Such a simple difference strategy would provide a consistent estimate as long as there were no changes over time that affected outcomes during the schedule changes (i.e., 1999 was a low crime year and 2002 was a high crime year). To account for possible confounding time effects, one can use a difference-in-difference (DID) strategy that only uses data from Friday and Saturday, but also has outcomes for the early evening of these days. With data for Friday and Saturday afternoon one can compare the difference between outcomes before and after the schedule change on Friday and Saturday afternoons to the difference between outcomes before and after the schedule change on Friday and Saturday late evenings. As long as any unobserved factor that affects Metro ridership and alcohol use over time has the same effect on early and late evening crimes, this DID approach should allow one to isolate the effect of Metro availability on outcomes. Since most DUI arrests occur after 10 pm, one may worry that time effects may differentially affect DUI and drinking behaviors at night versus during the early evening. To address this concern, we propose another round of differencing, using the difference between outcomes in the late night to those in the early evening before and after the schedule changes on Thursday (when there were no changes in Metro hours of operation over time) as the counterfactual change in outcomes for Friday and Saturday (when there were changes in the Metro's hours of operation over time). In other words, our DIDID approach identifies the effect of Metro availably on outcomes by comparing the difference in DID for Friday and Saturday to the DID on Thursday.

The DIDID identification strategy can be implemented by estimating the following equation by Ordinary Least Squares (OLS).

$$Y_{tds} = \alpha + \beta \cdot M_{tds} + \theta_{sd} + \theta_{td} + \theta_{st} + \varepsilon_{tds} \qquad [1]$$

Y_{tds} is the natural log of Metro riders, arrests, or traffic accidents at time of day *t*, on day of the week *d* during schedule *s*, M_{tds} is the number of hours of Metro operation during the time of the day. This variable is identified off the three-way interaction between day-of-week, time of day, and schedule. Since M_{tds} is defined by the three-way interaction, we need to control for all the two-way and one-way interactions. θ_{sd} θ_{td} and θ_{st} are effects for the two-way interactions between schedule and day of the week, time of day and day if the week, and schedule and time of the day, respectively.

The second potential source of variation is spatial in nature. It is reasonable to expect that neighborhoods close to Metro stations will be more greatly affected by the availability of Metro service than areas that are farther away from Metro stations. It is also reasonable to expect that larger effect on alcohol related outcomes in neighborhoods with several drinking establishments particularly if those drinking establishment are close to Metro stations. We test these hypotheses by seeing if the marginal effects of Metro availability vary by geography. Specifically we test if there are larger effects in areas that are close to Metro stations, areas than have a lot of drinking establishments and areas that are both close to Metro stations and are close to drinking establishments.

V Results

We present our results in three sections. First, we demonstrate that the increased hours of Metro availably was associated with increases in Metro ridership, and show that the increases in ridership are sufficiently large to potentially have an effect on late night alcohol related arrests and dui arrests. In the second section, we show the effects of the schedule changes on DUI arrests, and alcohol related arrests. We also show that the estimated effect follow geographic patterns consistent with our hypothesized mechanisms. Since variation in arrest outcomes could potentially be influence by changes in police behavior, as a check on the robustness of our results, in the final section we show the effect of the schedule changes on fatal car crashes (an outcome that is potentially *deflated* by policing bias).

V.1 Did Metro's Late Night Service Increase Public Transportation Use?

In order for public transportation to reduce DUIs, it has to be the case that potential drivers switched from private transportation to public transportation. While one cannot observe actual driving behaviors, we can observe Metro use. As long as increased Metro use reflects an increase in potential drivers switching from private transportation to public transportation, increases in Metro ridership should be associated with reductions in

DUI incidence, all else equal. We measure the average increase in ridership per additional hour of late night service by estimating the equation [1] where the outcome is the natural log of total riders. Note that each day in the WMATA data are parsed into four periods of time (unlike our arrest and traffic data) meaning we have 112 observations in the full sample.

Our estimates of the relationship between Metro availability and Metro ridership are displayed in table 3. Regardless of whether we use all days of the week (column 1), Thursday Friday and Saturday (column 2) or exclude the morning hours (column 3), we consistently estimate that each additional hour of service increases rider ship by 7 percent. However, this effect did change over time. In column 4 we estimate a more flexible model showing the effect of each of the three schedule changes separately, relative to the initial schedule. The dummies are multiplied by the additional number of hours Metro is open, so the coefficients can be interpreted as the change in ridership per hour across schedules. We find that having Metro open one additional hour (schedule 2) resulted in an imprecisely estimated 5 percent increase in ridership. Keeping the Metro open until 2am is associated with a 5 percent increase in ridership per hour (se=0.002), and keeping the Metro open until 3 am increased ridership by 7 percent per hour (se=0.002). As long as *some* of the increases in ridership overtime are among drinkers and prospective drunk drivers, we might expect to see the smallest change in alcohol related behavior when the Metro is only open until 1 am, with progressively larger changes with the later schedules.

Is a 7 percent change in ridership enough to generate measurable changes in risky behavior? There were an average of 6.8 million one-way Metro trips made on Friday and Saturday evenings when the Metro was open until midnight. A 7 percent increase in total ridership constitutes 1,064 additional riders per extra hour of Metro service. Given that there was roughly 1 DUI arrest and 3 alcohol related arrests per weekend night in DC when the Metro ran until 12 am, it is obvious that if just a fraction of those additional 1,064 additional riders were prospective drinkers and drunk drivers, enough riders were using the Metro to potentially induce a substantive and measurable change in intoxicated driving and alcohol consumption.

V.2. **Does Public Transportation Increase Alcohol Related Arrests and Reduce Intoxicated Driving Arrests?**

i. Aggregate Estimates:

Now that we have established at least some individuals used Metro's late night service, we use our arrest data to estimate equation [1] where the outcome is DUI arrests. Table 4 presents the results of these DIDID regressions, using only the time variation. There is one observation for each time of day, during each day of the week during each schedule period. Using all four schedules, seven days of the week, and three times of the day we have a total of 84 observations. To address the possibility that secular changes in crime may be correlated with the schedule changes, we also include results in which the outcomes is arrests for non alcohol related crimes.[22] The logic of this test is straightforward – if other confounding factors are correlated with the schedule changes, such as increased police enforcement or demographic changes, these factors should also affect other arrests and not just DUI arrests. If our results were driven by such confounding factors the effects on non-alcohol related arrests should be statistically significant *and* be in the same direction as the effect of DUI arrests and alcohol related arrests. As such, the lack of any substantively significant effect on other crimes would give us confidence that our effects on DUI and alcohol arrests are not driven by confounding factors and reflect a credible causal relationship.

< Table 4 >

Column 1 presents the naïve model using all the available data. If one interprets this regression causally, the estimates indicate that increasing the number of hours of Metro availability has a small imprecisely estimated negative effect on the number of DUI arrests, as well as a small and imprecisely estimated negative effect on alcohol related arrests (column 5). In addition, we find that expanding Metro service results in a statistically significant increase in arrests for "other" crimes (column 9). The fact that there is a statistically significant 14 percent increase in other arrests should give one pause in trusting the results from these specifications. However, recall from figure 1 that the temporal pattern of DUI arrests varies over days of the week, implying that arrests on Monday and Wednesday may not provide appropriate comparison groups for Friday and

[22] These arrests are essentially all crimes that are not DUIs, our definition of "alcohol related", or involve distributing alcohol to minors.

Saturday. In columns 2, 6, and 10 we present the DIDID model using only Thursday night (the best candidate evening) as the comparison night, as opposed to the entire week. In these models, each hour of Metro availability is associated with a statistically insignificant 18 percent reduction in DUI arrests and 8% increase in arrests for alcohol related crimes.[23] However, the effect on "other" arrests is both statistically and economically significant.

There is an important potentially confounding effect of the final schedule change. This change included not only an additional hour of Metro service late at night, between 2 and 3 am, but also one additional hour on Saturday and Sunday mornings- opening at 7 am instead of 8 am. As a result, our estimate of β will be identified in part off of this change in service on early Saturday morning. Since we are concerned only with the late night changes we exclude the early morning from our sample. Excluding the 5 am – 6 pm hours from our sample (columns 3, 7 and 11), doubles the size of our estimate of β, and reduces the precision of our estimate of the relationship between Metro service and "other" crimes. In this preferred model, each hour of Metro availability is associated with a statistically significant 44 percent reduction in DUI arrests, a statistically insignificant 4 percent increase in arrests for alcohol related crimes and a statically insignificant but sizable 24 percent increase in other arrests. Since the effect on other arrests is positive, we cannot rule out the possibility that the observed increase in alcohol related arrests is not due to secular increases in crime. However, it is compelling evidence that the *negative* effect of Metro availability on DUI arrests is a true negative effect.

Finally, in columns 4, 8 and 12, we relax our assumption that each additional hour of Metro service will have a constant effect on arrests. Our results suggest that the first service expansion (12 am to 1 am) was associated with a large and imprecise reduction in DUI arrests, but a 67 percent increase in arrests for alcohol related offenses. The next Metro schedule, with trains running until 2 am was associated with an 89 percent reduction in DUIs per hour, and an insignificant decrease in alcohol related crimes as well. Extending Metro hours from 2 am to 3 am is associated with a 36 percent reduction in DUI arrests per hour, and a corresponding 13 percent increase in alcohol related arrests

[23] Note that this approach will overstate the impact of Metro service on alcohol consumption and behavior if there is displacement in drinking from Thursday to Friday and Saturday nights. Focusing only on Fridays and Saturdays yields point estimates of equation one corresponding to a 25% reduction in DUIs per hour, and a 3% increase in alcohol related arrests, suggesting that this is not the case.

per hour of service. This is roughly consistent with our estimates of Metro ridership, where the 1st change had a substantial but statistically insignificant affect on ridership. The results for other arrests appear to bounce around with no consistent pattern.

In the table 5, we present "2SLS" estimates of public transportation DUI and Alcohol related arrests - essentially dividing the coefficient on Metro hours in table 4 by 0.07. This can be though of as a more formal test of the direct relationship between using public transportation and alcohol related behaviors, although we cannot split the early evening hours from the late evening hours, our first stage estimates do contain a bit of noise. Our results suggest that encouraging people to use public transportation instead of driving can cause significant reductions in intoxicated driving.

ii. Geographic Variation:

As discussed above, there is expected variation in the effect of Metro availability due to geography. In particular, if our proposed mechanisms are correct, one would expect that the marginal effects of greater Metro availability would be greatest in areas with a large number of drinking establishments, and in particular areas where those establishments are closer to Metro stations. For example, the Dupont Circle neighborhood has a centrally located Metro station (Dupont Circle) as well as an additional station within a ½ mile on pedestrian friendly city streets (Farragut North). In contrast, the Georgetown neighborhood is notoriously under-served by Metro, with the closest Metro station (Foggy Bottom) approximately mile away and on the opposite side of two highways (the Whitehurst Freeway and Rock Creek Parkway).

One could test for this type of response heterogeneity by including interactions of the main three-way effect with measures of geographic distance and the prevalence of alcohol venders. A more flexible approach would be to estimate the marginal effect of increased Metro hours for each PSA, and then to use the estimated marginal effects as data. This auxiliary regression approach is similar in sprit to Card and Krueger (1992), who estimate returns to schooling for each state and then regress the returns on state level characteristics. Specifically, we estimate equation [1] (excluding the mornings) for each of the 44 PSAs in our sample with valid alcohol vender data and then regress the marginal effect on PSA level characteristics.

Using 44 of the PSA level estimates as data, we test whether (1) areas with several drinking establishments experience greater reductions in DUI arrests and (2) areas where drinking establishments are farther away from Metro stations in general experience smaller reductions in DUI arrests.[24] First, we do a series of simple t-tests to compare the marginal effects across neighborhoods. In the 15 neighborhoods with at least one bar located within 100 meters of a Metro station, the average reduction in DUIs is 7 percent (se=0.07), compared to a 9 percent *increase* (se= 0.08) in the other 29 PSAs. In neighborhoods with fewer than 6 alcohol venders (the 25th percentile) the average change in DUIs is a 14 percent (se= 0.09) increase compared to a 2 percent decrease (se=0.07) for neighborhoods with more than 6 alcohol venders. The 21 PSAs with a Metro station within their boundaries have an average reduction of 3 percent (se=0.07), compared to the 23 other PSAs with an increase of 9 percent (se=0.09).

Examining the average coefficients for alcohol related arrests yields opposite relationships- on average alcohol related arrests fall by 8 percent (se=0.04) in areas without Metro accessible bars, and rise by 8 percent (se= 0.06) where there is at least one bar within 100 meters of a Metro. Alcohol related arrest fall by 9 percent (se= 0.07) in areas with less than 6 bars, and rise by 0.1 percent (se=0.04) in complimentary neighborhoods. While neighborhoods with a Metro station saw a reduction in DUI arrests as Metro expanded its hours, there was at the same time a 0.4 percent *increase* in alcohol related arrests.

While none of these differences (for DUIs or alcohol related arrests) are statistically significant at the 5 percent level of confidence, the consistency of the direction is striking. If the increase in alcohol related arrests reflects the change in the population drinking excessively, the reduction in "DUIs per drinker" is equal to the percentage change in DUI arrests minus the percentage change in Alcohol-related arrests, substantially increasing the magnitude of these differences across PSAs. In particular, neighborhoods with at least one bar within 100 meters of a Metro station have average

[24] We remind the reader that while this data are a stock of all existing licenses in 2008, most neighborhoods known for late night carousing have been under liquor license moratoriums since the late 1990s (District of Columbia Municipal Regulations Title 23 Chapter 3). As such, the number of licenses in a PSA was primarily determined before any of the schedule changes so the number of licenses was not a response to the schedule changed.

reductions in "DUIs per drinker" of 15%, versus increases of 17 percent in other neighborhoods- a different that is statistically significant at the 95 percent level of confidence.

< *figure 5* >

< *figure 6* >

As figures 5 and 6 show, there is a very suggestive pattern in the magnitude and direction of the "Metro effect" across neighborhoods. In figure 5, we report, for each PSA, the number of licensed alcohol venders within each neighborhood and indicate the location of each Metro entry point. It appears to be the cases that most, but not all, of the PSAs with multiple venders have larger reductions in DUIs per drinker with each hour of Metro service, but there are a few PSAs for which this is not the case. When we refine our measure of alcohol venders to only include those with 100 meters of a Metro station (figure 4) the pattern of marginal effects is striking. With the exception of the U street neighborhood, which is excluded from our analysis because the data on alcohol venders is incorrect, every PSA with more than 2 bars located within 100 meters of a Metro state has a reduction in DUIs per drink of at least 14% per hour of Metro service.

Comparing the marginal effects for non-alcohol related crimes across PSA characteristics yields very different conclusions; there are small reductions in arrests for non-alcohol related crime in PSAs with regardless of whether there are any "Metro accessible" bars (-2% where there are none and -8% where there is at least one), whether or not there are more than 6 bars (-2% if there is not, -5% if there is), and whether there is a Metro in the PSA (-0.4 ether way). None of these differences in means are statistically significant, suggesting that our results are not picking up confounding factors that affect arrests in general or that affect arrests or crime systematically across geographic areas.

To examine the geographic variation in Metro effects more formally, we take the PSA marginal effects and estimate the following equation by OLS.

$$\beta_P = \alpha + \pi_1 MetroAccess_P + \pi_2 AlcoholAccess_P + \theta Youth_P + \varepsilon_P \qquad [2]$$

In equation [2], β_p is the estimated DIDID coefficient on Metro from the arrests-based equation [1] estimated for PSA p. $MetroAccess_P$ is an indicator variable equal to 1 if PSA p has a Metro station located within its boundaries. $AlcoholAccess_P$ is a vector characterizing the number and proximity of alcohol venders to Metro stations in PSA p.

We also include a (time invariant) control for the fraction of the PSA population that is under 18, $Youth_p$, typically positively correlated with crime rates.

< *table 6* >

As the results in table 6 show, the regression results are consistent with our proposed causal mechanisms. While no coefficients are precisely estimated, what is striking is the opposite signs of the marginal effects on DUI arrests and alcohol related arrests in columns 1 and 2. Neighborhoods where the Metro is associated with larger reductions in DUI arrests had larger increases in alcohol related arrests. In column 3, we present estimate of the impact of Metro service on "DUIs per drinker". What emerges as the strongest predictor of the effect of Metro service on drunk driving is the number of "Metro accessible" bars. Each bar located within 100 meters of a Metro station is associated with a 0.6 percentage point reduction in DUIs. However, keeping the increase in alcohol consumption in those areas, we find that one additional hour of Metro service reduces the number of "DUIs per drinker" by 2 percentage points per "Metro Accessible" bar. Finally in column 4 we repeat this analysis for "other" less alcohol related arrests. Unlike the previous types of arrests, we cannot reject the null hypothesis that the coefficients on Metro and Alcohol accessibility are jointly zero at any reasonable level of confidence. In addition, there is no consistent pattern in the value or sign of the estimated coefficients individually.

In sum, the geographic results are consistent with our *a priori* notions, and they suggest that our effects work through the hypothesized channels. Specifically, areas with more alcohol selling establishment experience greater reductions in DUIs per drinker, PSAs that have a centrally located Metro station within their borders also experience larger reductions in DUIs per drinker, and PSAs that have more Metro accessible bars experience greater reductions in DUIs, conditional on the change in alcohol consumption. There are no such patterns for non alcohol related arrests.

V.3. Public Transportation and Fatal Accidents:

Our estimates strongly suggest that Metro's late night service reduced the incidence of intoxicated driving while increasing alcohol consumption. We argue that this is a true causal relationship based on two findings. First, we see that total public transportation use increased as Metro extended its operating hours and that temporal heterogeneity in the marginal effect of public transportation on rider ship is consistent with the observed temporal heterogeneity in the marginal effect of public transportation on DUIS and alcohol related arrests. Second, these effects were concentrated in areas where bars are located close to Metro stations. One of the concerns in using arrests as a measure of criminal activity is that it potentially confounds enforcement with incidence. To address this lingering concern, we examine variation in fatal alcohol-related car crashes, a measure of alcohol-impaired driving that is not inflated by stricter enforcement. Note that while on the margin, heavier DUI enforcement would reduce actual dunk drivers though incapacitation and deterrence, given that less than 1% of DUI incidents result in an arrest, these effects are likely to be trivial. In addition, any bias due to harsher DUI enforcement will *reduce* our estimated effects on alcohol related car crashes.

In our final analysis, we examine the impact the Metro extension had on fatal traffic accidents, complementing our analysis based on arrests. First, we identify the effect of the Metro extension on fatal traffic accidents by comparing the DID estimates in areas serviced by the Metro system (Washington D.C., Maryland suburbs and Virginia suburbs) to the DID effect in areas not-covered by the Metro system (other areas of Maryland and Virginia). Since one would expect the schedule changes to have an effect on covered areas, and no effect on non-covered areas, the DIDID effect in non-covered areas provides a credible control for underlying changes in fatal accidents over time for the covered areas. We implement this comparison by estimating equation [1] for areas that are covered and not covered by the Metro where the dependent variable is the natural log of traffic accidents involving alcohol. The data are defined by cells based on covered or not covered, state, time of day, day of the week and schedule.

< table 7 >

Table 7 shows the results for the covered and uncovered areas separately in columns 1 and 2 using all times of day and days of the week. According to this naive specification, one additional hour of Metro service after midnight increases fatal crashes by 0.7 percent in non-covered areas while decreasing fatal crashes in covered areas by 5.2 percent. Columns 3 and 4 present the same results using only the Thursday through

Saturday data and without the morning hours. Unlike the results in Columns 1 and 2, in this model there is virtually no difference in effect between covered and not covered areas. Recall from Figure 4 that unlike for arrests, Thursday fatal crashes do not track Friday and Saturday night fatal crashes very well - suggesting that it is not a good control. As such, we present results using only Friday and Saturday night data in columns 5 and 6. According to this specification, one additional hour of Metro service after midnight reduces fatal crashes by 5.9 percent in non-covered areas while decreasing fatal crashes in covered areas by 11.6 percent.

While the results in columns 5 and 6 show larger reductions in areas serviced by the Metro they do not constitute a formal test. In columns 7 and 8, we combine all data for covered and not-covered areas to test for a differential effect formally. Specifically, we estimate a model for all areas and include an indicator variable for whether the area is covered and an interaction term between whether the area is covered and the hours of Metro operation. Note that this model assumes that time shocks are the same across covered and not-covered areas. Column 7 shows results that use Thursday through Saturday data excluding the morning hours. In this model the coefficient on the interaction term is -0.101 indicating that expanding the hours of operation by one hour reduces the number of fatal crashes in covered areas by 10 percent relative to uncovered areas. Column 8 does the same comparison using only the Friday and Saturday data. In this model, the coefficient on the interaction term is -0.112 indicating that expanding the hours of operation by one hour reduces the number of fatal crashes in covered areas by 11.2 percent relative to uncovered areas. While these effects are not statistically significant, the point estimate indicate that uncovered areas experienced a decrease in the number of fatal crashes when the Metro expanded its hours of operation.

There is also a spatial component to the hypothesized effect of Metro service on traffic accidents. Specifically, public transportation may have displaced intoxicated driving, and thus fatal accidents, from the District of Columbia to suburban Maryland and Virginia. To see this, consider an individual who previously drove from the suburbs to DC in order to drink in a bar then drove back to the suburbs causing a fatal traffic accident in either DC or the suburbs. Now, consider an otherwise identical potential driver who has the option of using public transportation. This individual may drive to the suburban Metro stop and then use the Metro to get from the suburbs to DC. This individual will not be involved in a fatal traffic accident in DC, but they will be at risk of an accident in the suburbs if they drive themselves from the Metro station to their home. In sum, while we expect that Metro service should reduce intoxicated driving in DC, the net effect in Maryland and Virginia is unclear. To allow for the most flexibility in the relationship between public transportation and fatal alcohol related traffic accidents, we estimate state specific versions of equation [3] below.

$$FA_{tds} = \alpha + \theta FNA_{tds} + \beta M_{tds} + \theta_{sd} + \theta_{td} + \theta_{st} + \varsigma_{tds} \quad [3]$$

Where F_{tds} is the natural log of traffic accidents involving alcohol, and FNA_{tds} is the natural log of traffic accidents which alcohol was not a factor. Since all of D.C. is serviced by Metro, we have no natural geographic control. While we do not expect non-alcohol related accidents to be correlated with Metro service, this is a natural control for unobserved variation in accidents due to road conditions, traffic density, and the changing age composition of the population. Since several crashes do not report whether alcohol was a factor, controlling for non-alcohol related accidents could potentially be over controlling such that we would find no effect even if there were one. As such, results from this model are likely to produce a lower bound estimate. Since, relative to the arrest data, there are fewer crashes on Thursdays relative to the weekends, we will also present results only at Friday and Saturday.

< table 8 >

Our estimates relating public transportation to intoxicated driving by state are displayed in table 8. The results for the entire DC metropolitan area based on the Thursday through Saturday data in Columns 1 and 2 suggest that there may be no substantively or statistically significant relationship between Metro service and traffic fatalities, regardless of whether or not we control for general road conditions. However, results in column 1 using Friday and Saturday only in the lower panel indicate that there may have been an overall reduction. However, conditional on non-alcohol related crashes there may be no overall effect. Since these results may suffer from attenuation bias due to over controlling (i.e. some other car crashes may involve alcohol but are not coded as such) we do not take this as conclusive evidence of no effect. In any case, it is unclear whether or not we would expect traffic accidents to fall in the suburbs if intoxicated bar patrons drove from suburban Metro stations to their homes.

In columns 3 and 4, we restrict our attention to alcohol related traffic accidents in DC only. Once we control for the number of non-alcohol related crashes, we estimate that an additional hour of late night Metro service reduced fatal alcohol related crashes by 78% (se=0.34). In the Maryland suburbs, (columns 5 and 6) an additional hour of Metro services is associated with an imprecisely estimated 13% reduction (se=0.18) in fatal crashes, and in suburban Virginia we estimate a 3% reduction (se=0.27) per hour of Metro service. While this is not evidence of a pure displacement of intoxicated drivers from the District to the suburbs, it does appear to be the case that DC was the primary beneficiary of the Metro expansion. In the bottom panel of table 5, we repeat the above analysis, but without Thursday accidents as a comparison group. Our results are not driven by variation in Thursday, although only comparing Friday and Saturdays before and after Metro expansion suggests that there may have been some displacement of intoxicated driving from DC to the Virginia suburbs.

In sum, the results in Tables 7 and 8 suggests that the Metro expansions were associated with reductions in fatal crashes in Washington DC. The results using uncovered areas as a point of comparison show that the Metro expansions were associated with reductions in fatal crashes overall, while results that use non-alcohol related crashes as a control provide mixed results. Using Thursday as a control day, we find that Metro expansions were associated with reductions in fatal crashes in all areas, while using only data from Friday and Saturday we find reductions in D.C. and Maryland, with *increases* in Virginia suburbs - perhaps suggestive of some geographic displacement.

VI. Conclusions

Excessive alcohol consumption imposes large costs on society as well as the individual drinker. In particular, driving under the influence of alcohol is estimated to cost society $51 billion a year. Governments and social groups also attempt to reduce the social cost of drinking by lowering the private cost of driving under the influence of alcohol, or providing a “safer option”. These policies range from providing free or subsidized taxi service on New Year's Eve to temporary expansions of public transportation services during major athletic events. These well-intentioned services also generate the potential for moral hazard, since the safe ride home reduces the personal cost of alcohol consumption. The primary mechanism through which public transportation should affect DUIs is by allowing people who drink at bars to ride, as opposed to drive, home. Despite the large potential benefits to increasing public transportation availability, there are no empirical studies documenting a relationship between DUIs, alcohol consumption and public transportation.

We identify the impact of a change in public transportation availability using a triple-difference approach that compares arrests for DUIs and other alcohol related crimes over time, during different days of the week, and across neighborhoods in Washington DC. While our estimated effect are rather imprecise, they constitute the first and the best evidence on the important question of whether one reduce the socially deleterious effects of drinking, by providing drinkers a safe way home. We find that as the DC Metro expanded its late night hours of operation, the number of DUIs fell by approximately 7% per hour of service in areas in which drinkers were better serviced by Metro. We also find evidence that the reduction in DUIs may have been associated with an increase in out-of-home alcohol consumption. As Metro service expanded the number of arrests for alcohol-related crimes increased by as much as 8% in "Metro accessible" neighborhoods, suggesting that late-night Metro service caused large increase in the drinking population. Using arrests for these crimes as a proxy for changes in the size of this typically non-measurable population, we estimate that expanding Metro's hours of operation from midnight to 2 am reduced the number of drinkers who drove home by 15.6% per hour in these neighborhoods. The magnitude of the effect warrants attention. At the same time, the benefit of reduced DUIs per drinker dissipates rapidly as alcohol venders become more remote to Metro stations.

Providing drinkers with a safer way home does appear to reduce the incidence of intoxicated driving, reducing the total external cost of alcohol consumption. This social benefit should be weighed cautiously against the corresponding increase in risky alcohol consumption. Based on our estimate of a 7% reduction in DUIs per hour, approximately

403 DUI arrests were avoided by Metro operating between 12 am and 2 am.[25] If approximately 1% of DUI incidents result in arrest, then this reduction in arrests corresponds with 40,300 fewer incidents of intoxicated driving. With an average social cost of $21,500 per incident [Miller, Cohan and Wiersema 1996], this corresponds with a savings of $866 million over five years. If the external cost of consuming an ounce of ethanol, excluding intoxicated driving, is 25.5¢ [Manning et al.1991], then an additional 26 million gallons of ethanol would have to have been consumed between 12 and 2 am on Fridays and Saturdays during 1999 and 2003- 6.5 million additional gallons per year. In 1998, 1.676 million gallons of ethanol were sold in DC, and between 1999 and 2003 this increased at an average annual rate of 2.7%, or 38 thousand gallons per year.[26] Although alcohol consumption increased, it seems highly plausible that the social benefit due to reduced DUIs outweighed the social cost of additional alcohol consumption.

Finally, controlling for the prevalence of non-alcohol related accidents, we estimate that each additional hour of late night public transportation reduces fatal accidents involving intoxicated drivers by 70%. While the social benefit of providing a "safer option" for drinkers appear to be localized to areas directly served by the Metro, it does appear to be the case that even excessive drinkers respond to changes in costs in a rational way.

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[25] A total of 2,666 arrests were made during schedules 2 and 3. The 403 estimate is generated by assuming that DUI arrests were 7% lower than they could have been during schedule 2 and 14% lower than they could have been during schedule 3.
[26]Estimate taken from the National Institute Alcohol Abuse and Alcoholism http://www.niaaa.nih.gov/Resources/DatabaseResources/QuickFacts/AlcoholSales/consum02.htm

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Figures:

Figure 1

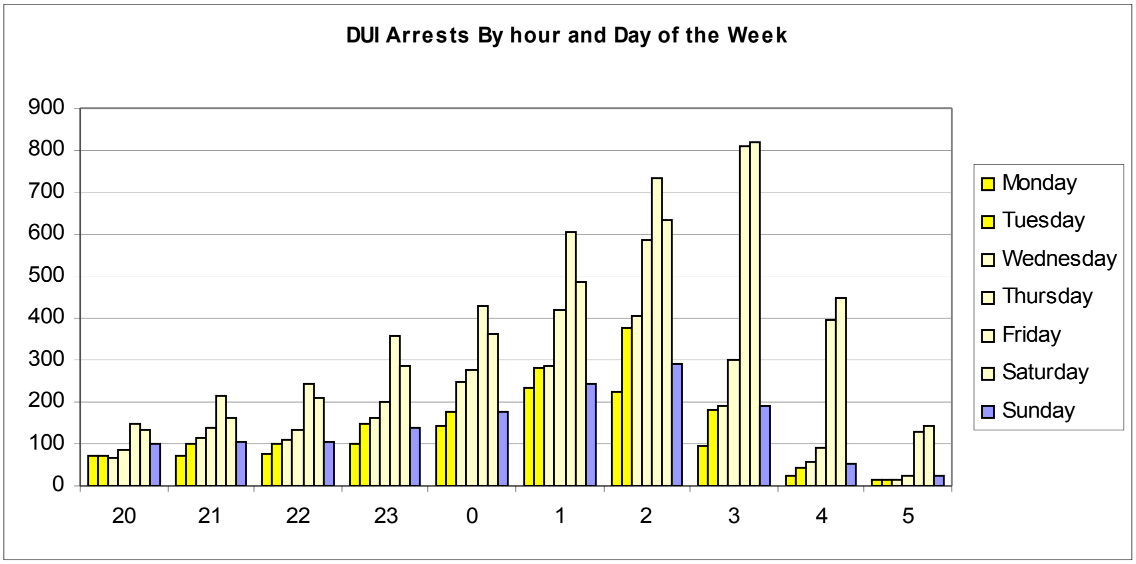


Figure 2

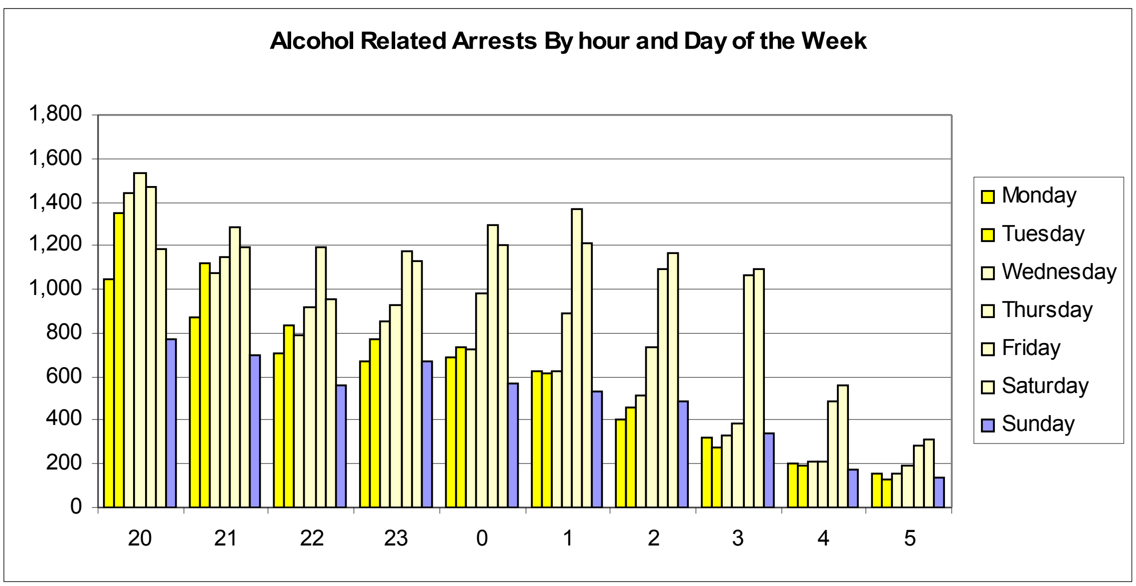


Figure 3: Alcohol Venders and Metro Stations in Washington, DC

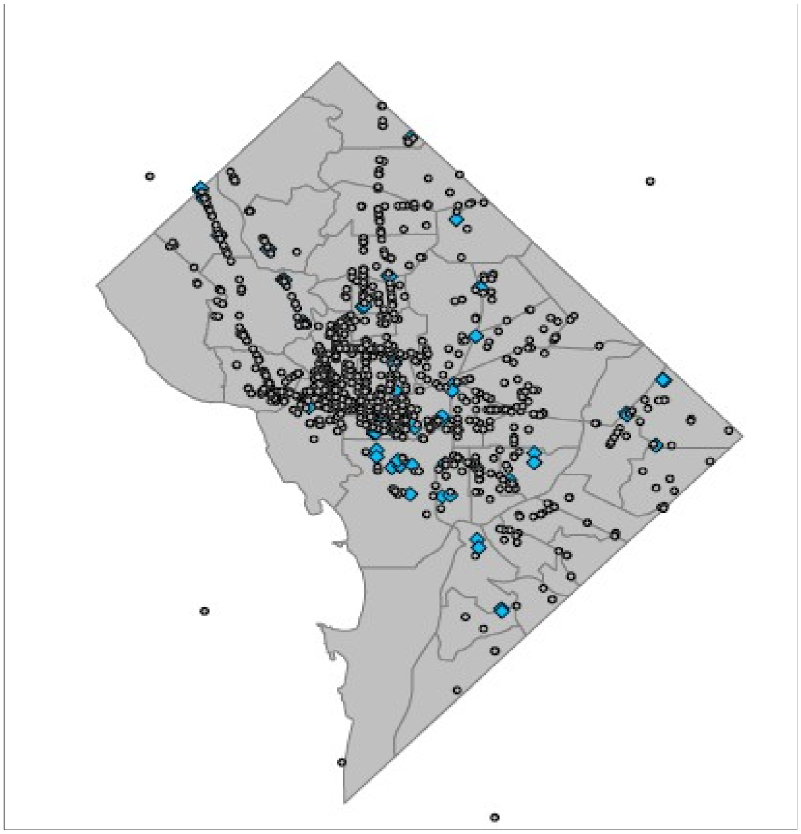


Figure 4

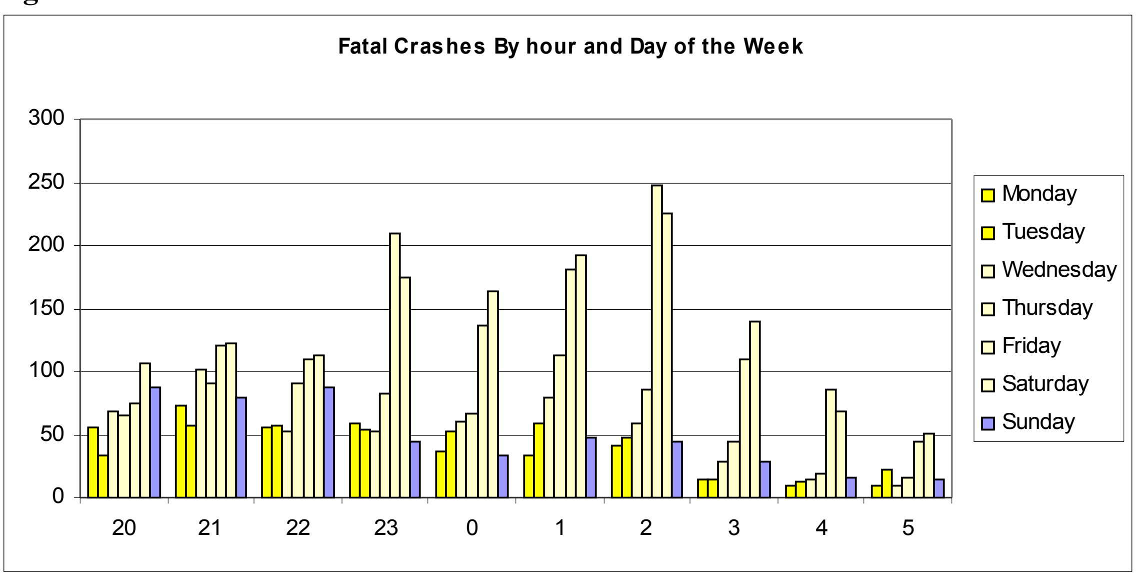
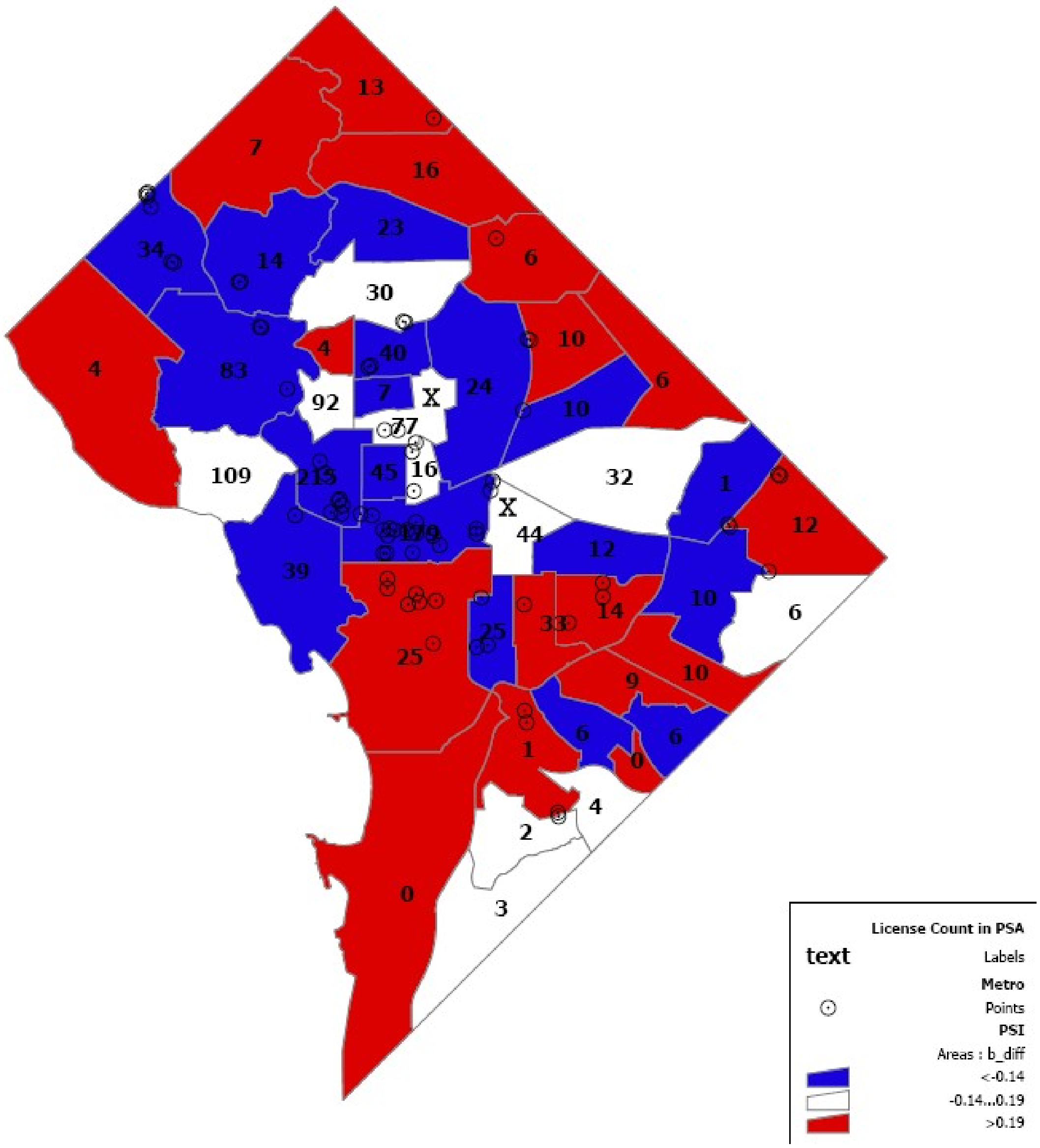
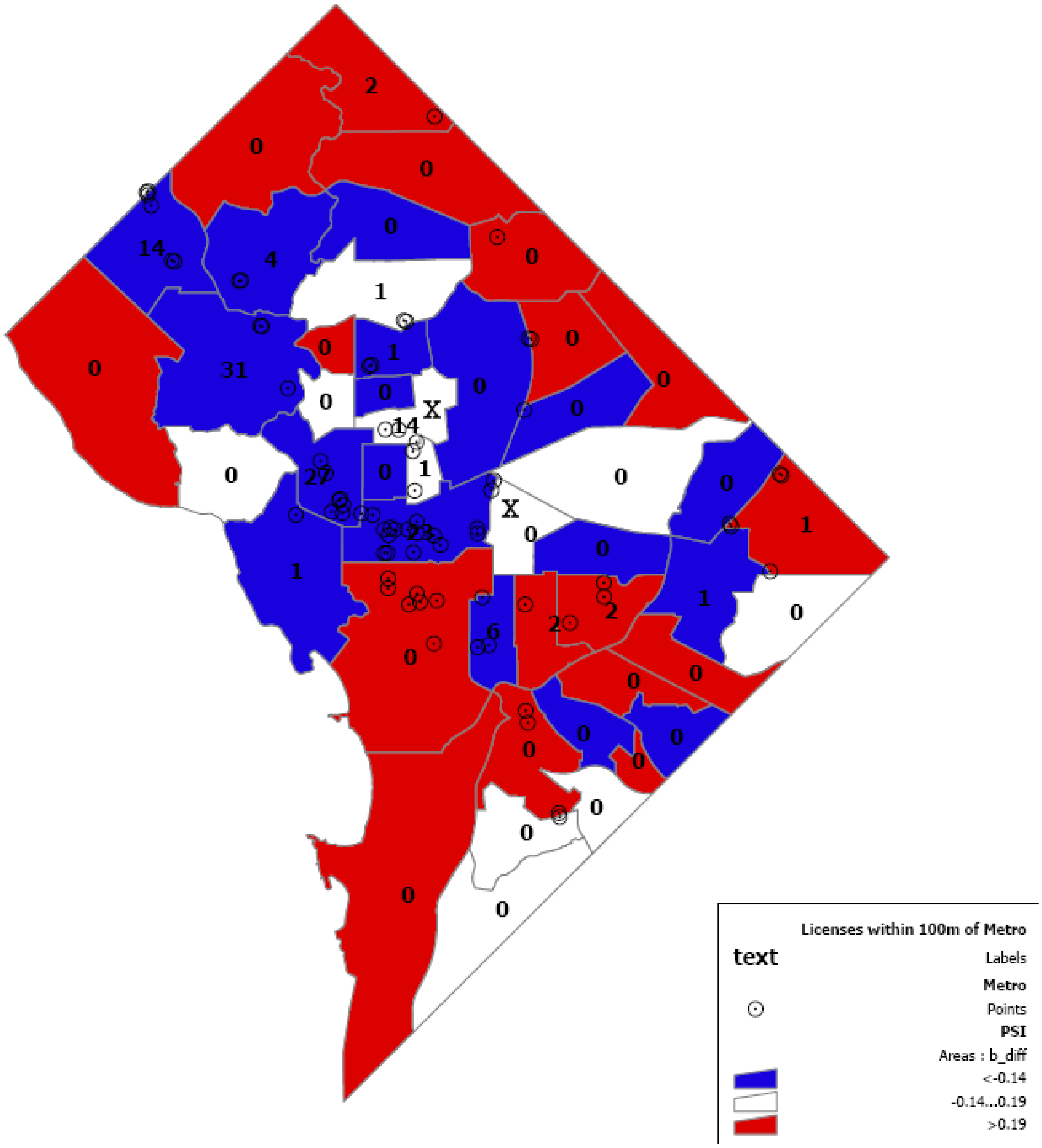


Figure 5: Distribution of Marginal Effects Across PSAs, by Number of Alcohol Venders



Note: U street and H street corridors, excluded from analysis, are marked with an "X"

Figure 6: Distribution of Marginal Effects Across PSAs, by Number of Alcohol Venders within 100m of Metro Station



Note: U street and H street corridors, excluded from analysis, are marked with an "X"

Tables:

Table 1: Mean Neighborhood Arrests across Metro schedule by Day of the Week and Time of Day

		Morning	Evening	Late Night
Weekly	DUIs	1.23	1.60	9.01
		(2.31)	(2.43)	(20.1)
	Alcohol - Related	59.1	30.8	28.2
		(93.6)	(37.3)	(41.4)
Sunday	DUIs	2.27	1.76	6.29
		(3.38)	(2.66)	(10.17)
	Alcohol - Related	45.33	21.57	21.69
		(48.93)	(22.38)	(24.79)
Monday	DUIs	0.92	1.24	4.70
		(1.68)	(1.87)	(7.72)
	Alcohol - Related	66.60	28.96	23.49
		(118.83)	(34.07)	(23.27)
Tuesday	DUIs	1.06	1.42	6.83
		(1.63)	(1.89)	(12.88)
	Alcohol - Related	76.36	39.59	25.59
		(108.32)	(42.88)	(26.34)
Wednesday	DUIs	0.91	1.51	7.72
		(1.48)	(2.00)	(13.71)
	Alcohol - Related	77.46	41.23	26.50
		(114.69)	(41.50)	(28.73)
Thursday	DUIs	0.95	1.74	10.56
		(1.61)	(2.06)	(19.91)
	Alcohol - Related	77.57	41.11	32.71
		(109.39)	(41.48)	(39.65)
Friday	DUIs	1.15	2.69	18.84
		(1.78)	(3.50)	(33.32)
	Alcohol - Related	66.42	40.54	49.23
		(83.87)	(41.31)	(64.77)
Saturday	DUIs	2.55	2.43	17.15
		(3.66)	(2.88)	(30.92)
	Alcohol - Related	62.76	33.09	46.68
		(72.47)	(33.01)	(60.46)

Standard deviations in parentheses. The unit of observation is a PSA-Schedule. As the location of alcohol selling establishments is not relevant for the arrest analysis, each cell contains 184 observations

Table 2: Alcohol Venders in Police Service Areas

	All PSAs	U and H Street corridors Excluded
N	46	44
# Venders	29.5	28.1
	(44.0)	(44.3)
Minimum	0	0
Maximum	215	215
# Venders within 100m of Metro	2.84	2.66
	(7.16)	(7.11)
# Venders within 400m of Metro	13.5	12.6
	(35.5)	(35.4)
# Venders within 800m of Metro	20.0	19.0
	(41.3)	(41.4)
Mean Distance from Venders to Metro (meters)	891.9	904.9
	(566.8)	(571.3)
Minimum	187	187
Maximum	2439.5	2439.5
Minimum Distance from Venders to Metro (meters)	486	500.9
	(558.7)	(566.8)
Minimum	14	17.2
Maximum	2204.2	2204.2

Standard deviations in parentheses

Table 3 : OLS Metro Availability and Metro Ridership

	(1)	(2)	(3)	(4)
Metro Hours	0.074	0.066	0.068	
	[0.018]*	[0.014]*	[0.015] *	
Weekend Evening x 2nd Schedule x 1 hour				0.053
				[0.065]
Weekend Evening x 3rd Schedule x 2 hours				0.050
				[0.022]*
Weekend Evening x 4th Schedule x 3 hours				0.070
				[0.015]*
R-squared	0.99	0.99	0.99	0.99
Observations	112	48	36	36
Days of the week	All	Thurs, Fri & Sat	Thurs, Fri & Sat	Thurs, Fri & Sat
Morning Included?	Yes	Yes	No	No

There was an average of 30,506 one way trips taken each day during the evening weekend hours prior to November 5th 1999. All equations include a complete set of schedule x time of day, time of day x day of week, and schedule x day of week fixed effects. Robust standard errors in brackets. + significant at 10%; * significant at 5%

Table 4 : OLS estimates of Arrests and Metro Availability

	Log(DUI)				Log(Alcohol Related)				Log(Other)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Metro Hours	-0.017	-0.184	-0.438		-0.025	0.083	0.040		0.140	0.254	0.233	
	[0.118]	[0.229]	[0.200]*		[0.057]	[0.070]	[0.098]		[0.058]*	[0.095]*	[0.132]+	
Weekend Late Night x 2nd Schedule x 1				-0.667				0.667				-0.558
				[0.471]				[0.222]*				[0.300]+
Weekend Late Night x 3rd Schedule x 2				-0.896				-0.074				0.087
				[0.170]*				[0.135]				[0.114]
Weekend Late Night x 4th Schedule x 3				-0.360				0.130				0.180
				[0.099]*				[0.015]*				[0.076]*
R-squared	0.97	0.97	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Observations	84	36	24	24	84	36	24	24	84	36	24	24
Days of the week	All	Thurs, Fri & Sat	Thurs, Fri & Sat	Thurs, Fri & Sat	All	Thurs, Fri & Sat	Thurs, Fri & Sat	Thurs, Fri & Sat	All	Thurs, Fri & Sat	Thurs, Fri & Sat	Thurs, Fri & Sat
Daytime Included?	Yes	Yes	No	No	Yes	Yes	No	No	Yes	Yes	No	No

There was an average of 0.99 DUI arrests, 2.7 alcohol related arrests, and 4 other arrests each day during the late weekend nights prior to November 5th 1999. All equations include a complete set of schedule x time of day, time of day x day of week, and schedule x day of week fixed effects. Robust standard errors in brackets. + significant at 10%; * significant at 5%

Table 5 : Metro Public Transportation and Drunk Driving (Log DUI)

	(1)	(2)	(3)	(4)
Metro Hours	-0.027	-0.306	-0.302	
	[0.170]	[0.290]	[0.324]	
Metro Trips				-4.45
				[4.66]
R-squared	0.99	0.99	0.99	0.96
Observations	112	48	36	36
Days of the week	All	Thurs, Fri & Sat	Thurs, Fri & Sat	Thurs, Fri & Sat
Morning Included?	Yes	Yes	No	No

There was an average of 30,506 one way trips taken each day during the evening weekend hours prior to November 5th 1999. All equations include a complete set of schedule x time of day, time of day x day of week, and schedule x day of week fixed effects. Robust standard errors in brackets. + significant at 10%; * significant at 5%

Table 6: Geographic Variation Associated with Metro and Alcohol Related Behavior

	Log(DUI)	Log(Alcohol Related)	Log(DUI) - Log(Alcohol Related)	Log (Other)
	(1)	(2)	(3)	(4)
Venders	0.001	0.001	0.001	0.002
	[0.002]	[0.002]	[0.003]	[0.002]
Venders > 6	-0.117	0.003	-0.119	-0.039
	[0.180]	[0.114]	[0.220]	[0.091]
Metro Station in PSA	-0.022	0.003	-0.025	0.030
	[0.169]	[0.098]	[0.203]	[0.085]
Venders < 100m	-0.006	0.017	-0.023	0.001
	[0.007]	[0.003]*	[0.009]*	[0.014]
Venders < 400m	0.007	-0.008	0.015	0.007
	[0.007]	[0.005]+	[0.009]	[0.006]
Venders < 800m	-0.008	0.005	-0.013	-0.008
	[0.006]	[0.005]	[0.008]	[0.006]
Pop under 18 (x 100)	-0.008	-0.002	-0.005	0.002
	[0.003]*	[0.003]	[0.004]	[0.002]
Constant	0.363	-0.026	0.389	-0.078
	[0.160]+	[0.108]	[0.209]	[0.108]
R-squared	0.17	0.18	0.07	0.03
Observations	44	44	44	44
P(F>f)	0.09	0.00	0.03	0.84

The dependent variable in each regression consists of neighborhood specific estimates of β from Table 4, column 3, 7 and 11. Robust standard errors in brackets. + significant at 10%; * significant at 5%

Table 7: Fatal Automobile Accidents and Metro Availability in DC, Maryland and Virginia (Covered vs. Not Covered Areas)

	Not Covered	Covered	Not Covered	Covered	Not Covered	Covered	All	All
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Metro hours	0.007	-0.052	0.043	0.052	-0.059	-0.116	0.109	-0.026
	[0.131]	[0.226]	[0.267]	[0.411]	[0.139]	[0.237]	[0.236]	[0.132]
Metro hours*Covered							-0.101	-0.112
							[0.110]	[0.146]
Covered							-1.453	-1.38
							[0.372]*	[0.531]*
R-squared	0.81	0.57	0.87	0.65	0.9	0.61	0.81	0.79
Observations	168	252	48	72	32	48	120	80
Days of the week	All	All	Thurs, Fri & Sat	Thurs, Fri & Sat	Fri & Sat	Fri & Sat	Thurs, Fri & Sat	Fri & Sat
Morning Included?	Yes	Yes	No	No	No	No	No	No

All equations include a complete set of schedule x time of day, time of day x day of week, and schedule x day of week fixed effects.
Robust standard errors in brackets.

Table 8: Fatal Automobile Accidents and Metro Availability by State

	DC Metro Area		Washington, DC		Maryland Suburbs		Virginia Suburbs	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Metro Hours	0.029	0.023	0.140	-0.781	-0.152	-0.135	0.169	-0.029
	[0.211]	[0.168]	[0.318]	[0.345]+	[0.167]	[0.183]	[0.203]	[0.274]
		0.850		-1.221		0.538		0.371
Log (Non-alcohol related accidents)		[0.103]*		[0.340]*		[0.474]		[0.336]
R-squared	0.93	0.97	0.99	0.98	0.99	0.99	0.98	0.99
Observations	72	72	24	24	24	24	24	24

Friday and Saturday Only

	DC Metro Area		Washington, DC		Maryland Suburbs		Virginia Suburbs	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Metro Hours	-0.115	0.009	-0.514	-0.912	0.022	-0.160	0.143	0.211
	[0.237]	[0.142]	[0.303]+	[0.330]*	[0.078]	[0.057]*	[0.082]	[0.056]*
Log (Non-alcohol related		0.484		-1.223		0.567		0.722
accidents)		[0.087]*		[0.379]*		[0.124]*		[0.214]*
R-squared	0.61	0.80	0.978	0.99	0.99	0.99	0.93	0.99
Observations	48	48	16	16	16	16	16	16

All equations include a complete set of schedule x time of day, time of day x day of week, and schedule x day of week fixed effects. Robust standard errors in brackets. + significant at 10%; * significant at 5%

Appendix:

Alcohol-Related Crimes
excluding crimes consisting of less than 0.1% of total

Offense	Percent
Affrays	1.38
Assault Simple in Menacing Manner	**21.93**
Assault Threatened in Menacing Manner/T	0.98
Assault w/Intent to Commit Any Other Of	0.18
Attempt Theft	0.27
Conspiracy/Threats (Felony)	1.13
Destroying or Defacing Buildings/Other	0.1
Disorderly (Craps)	1.21
Disorderly (Jostling)/Other Disorderly	**4.57**
Disorderly Conduct (Incommoding)	0.46
Disorderly Conduct (Loud & Boisterous)	**5.65**
Disorderly Conduct (Obscene Gestures)	0.04
Disorderly Conduct in Public Building	0.1
Drinking in Public	**2.18**
Indecent Exposure	0.17
Indecent Sexual Proposal	0.16
Metro Misconduct	0.51
Other Felony Offense	6.71
Other Misdemeanor Offense	**17.89**
Other Non-Aggravated Assault	0.48
Possession Open Container of Alcohol	**19.07**
Robbery -- Force & Violence	1.01
Robbery -- Purse snatch (Force)	0.23
Robbery/Attempt to Commit Robbery	0.58
Shoplifting	1.19
Theft 1st Degree	**1.99**
Theft 2nd Degree	**2.89**
Theft from Auto I	0.24
Unlawful Assembly	0.4
Unlawful Entry on Property	**3.22**
Urinating in Public	**2.2**