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DISSERTATION

Essays on Environmental Determinants of Health Behaviors and Outcomes

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This document was submitted as a dissertation in August 2007 in partial fulfillment of the requirements of the doctoral degree in public policy analysis at the Pardee RAND Graduate School. The faculty committee that supervised and approved the dissertation consisted of Roland Sturm (Chair), Rosalie Liccardo Pacula, and Lionel Galway. Brian Finch of San Diego State University was the external reader for the dissertation.

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My wife has always supported my decisions. Her extraordinary efforts to overcome all types of difficulties and make our life in foreign land comfortable and fun are deeply appreciated. I dedicated this dissertation to my wife and children!

Abstract

The conventional view of linking individual choice of lifestyle to health outcomes is being challenged. Researchers and policy makers are increasingly aware of contextual influences on people's behaviors and health outcomes. Embracing the literature on environmental determinants of health with a focus on methodology, this dissertation focuses on alcohol and food environments. Four stand-alone essays respectively examine: i) Disparities in alcohol environments and their relationship with adolescent drinking; ii) Spatial location of alcohol outlets and problem drinking among the adult population; iii) Weight gain trend across sociodemographic groups in the U.S.; and iv) Retail food environments and obesity.

Of $116.2 billion expenditure on alcohol in 1999, $22.5 billion was attributed to underage drinking and $34.4 billion attributed to excessive adult drinking in United States. Researchers have documented many health and social problems related to alcohol misuse. The analyses in this dissertation show that there is consistent evidence of a concentration of alcohol retailers in minority and low-income neighborhoods in California. Furthermore, alcohol outlets located in close proximity to homes are significantly associated with adolescents' binge drinking and driving after drinking. In particular, some types of alcohol outlets are found to be associated with excess alcohol consumption and heavy episodic drinking among the adult population. Disparities in alcohol-related health risks can be exacerbated by alcohol retailers' direct effects on problem drinking and indirect effects such as drunk driving and violent crime.

Approximately 300,000 deaths among the U.S. adults are attributable to obesity annually. The Department of Health and Human Services has made the problem of

overweight and obesity one of its top priorities. Sociodemographic disparities in obesity are well-documented, and there are different hypotheses to explain widening or narrowing trends in unhealthy weight. One of the most striking findings in this dissertation is that in contrast to the sharp image of disparities depicted by a snapshot approach, weight gain trend is quite similar across sociodemographic groups. The weight distribution curve shifts to the right probably due in part to broadly environmental factors such as transportation and community design. Retail food outlets, an important aspect of the built environment, are also found to be associated with individual obesity status. In addition to targeting high-risk groups, the population strategy deserves further attention. Improving the supply of and access to healthy food choices can play a role in the prevention of obesity.

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Chapter 1: Introduction

Understanding risk factors and interventions that address individual health practices have greatly contributed to improving health and reducing health disparities in the United States (U.S. Preventive Services Task Force, 1996). However, relatively little is known about the mechanism and processes through which community contextual factors interact and affect individual health (Hillemeier et al., 2003). The Healthy People in Healthy Communities Report describes a healthy community as one that continuously creates and improves both its physical and social environments, helping people to support one another in aspects of daily life and to develop to their fullest potential (U.S. Department of Health and Human Services, 2001). This broad definition warrants further research to advance our understanding of how communities affect health and what interventions are needed to implement to provide wide-ranging health benefits. It remains a challenge for researchers to develop theories, build models, conceptualize and capture characteristics of places into concrete measures for meaningful analyses. Constructs like neighborhood or community are highly subjective and the literature does not even have consistent terminologies for them. The difficulties in understanding what aspects of broadly defined environmental factors to consider and how to measure them are reflected in the fact that this literature remained mired in a poverty paradigm for an extended period of time (Rowley et al., 1993).

The proposition of linking individual choice of lifestyle to health outcomes is being revisited. From a prevention perspective, choices are not made in a vacuum. Individuals make choices under various constraints and the environments in which individuals live out their daily lives can have significant influence over their health behaviors and outcomes (Lynch, Kaplan, and Salonen, 1997; Lynch and Kaplan, 2000; Macintyre et al., 2002). New research opportunities are emerging thanks to the newly developed data infrastructure, statistical software, and computational power. Contextual factors have recently been examined in relation to a wide range of health outcomes such as mental illness (Leventhal and Brooks-Gunn, 2003; Goldsmith, 1998; Silver et al, 2002; Schieman and Meersman, 2004), physical health (Lee and Ferraro, 2007; Sturm and Debora, 2004), obesity (Frank et al., 2004 and 2005; Rundle et al., 2007; Gordon-Larsen, 2006), cardiovascular disease and mortality (Diez-Roux et al. 2001; Karpati et al., 2006; Chaix et al., 2007), tuberculosis (Barr et al., 2001; Acevedo-Garcia, 2001), and adverse birth outcomes (Farley et al., 2006; Grady, 2006; Pearl, 2001). Corresponding to the respective health outcomes, different categories of contextual factors have been investigated, varying by their nature and measuring methods such as sociodemographic characteristics (Ostir et al, 2003; Reijneveld et al, 1998 & 2000), risky factors (Hill and Herman-Stahl, 2002; Rosenthal, 2002), built/physical environments (Weich, 2002; Birtchnell, 1998), subjective assessments (Leventhal and Brooks-Gunn, 2003; Cohen et al., 2006; Scott et al., 2007); individual measures (Kling et al., 2005; Schulz et al., 2000;), and composite indices (White et al., Ross et al., 2000).

Many studies have found significant relationships between the environmental factors and individual health behaviors and outcomes, though cautious interpretation is often needed to claim causal effects. A few typical studies can be given. Four to seven years after random assignment, mental health of adults of families offered vouchers in safer neighborhoods was found substantially better than those of the control group not offered vouchers. The results were consistent across specific measures of mental health (Kling et al., 2005). A robust association between suburban sprawl and physical health was found (Sturm and Cohen, 2004), and measures of the built environment and travel patterns are important predictors of obesity across gender and ethnicity (Frank et al., 2004). Neighborhood disadvantage is related to rates of cardiovascular death in elderly white adults (Diez-Roux et al., 2004). And measures of neighborhood economic conditions are associated with both fetal growth and the length of gestation independent of individual-level factors (Farley et al., 2006).

As stated by the title, this dissertation embraces a broad interest in plausible effects of environmental factors on individual health behaviors and outcomes. After the literature review and methodology section, it will focus on the alcohol and food environments. Four stand-alone essays will respectively examine: i) Disparities in alcohol environments and their relationship with adolescent drinking; ii) Spatial location of alcohol outlets and problem drinking among the adult population; iii) Weight gain trend across sociodemographic groups in the US; and iv) The link between the obesity epidemic and food environments. The first two essays focus on neighborhood environments whereas the last two essays address broader contextual factors.

Disparities in Alcohol Environments and Adolescent Drinking

Of $116.2 billion expenditure on alcohol in 1999, $22.5 billion was attributed to underage drinking and $34.4 billion was attributed to adult excessive drinking in United States (Foster et al., 2003). Despite it being illegal, underage drinking remains highly prevalent. About 73 percent of students have consumed more than just a few sips of alcohol by the end of high school (Johnston et al., 2007). Estimated cost of underage drinking is about $52.8 billion in 1996 (Levy et al., 1999). There are many health and social problems associated with youth alcohol use and they are the cause of substantial societal costs (Levy et al., 1999). As the chance for underage drinkers to obtain alcohol from commercial sources is high (Forster et al., 1994, 1995; Freisthler et al., 2003), neighborhood outlets are likely to play an important role in underage drinking. In California, retail licenses are not typically approved within 100 feet of a residence or within 600 feet of schools, public playgrounds and nonprofit youth facilities, but proximity by itself is not sufficient to deny the license. Thus, concentration of alcohol outlets in disadvantaged neighborhoods is a possibility and that may cause minority and low-income people to suffer disproportionately from alcohol-related and exacerbate health disparities across sociodemographic groups. Novel methods will be employed to examine the locational pattern of alcohol sales around residences of people in different sociodemographic status and whether commercial alcohol outlets in close proximity actually play a role in adolescent drinking.

Spatial Location of Alcohol Outlets and Adult Problem drinking

Ecological studies find that alcohol sales are associated with alcohol related problems such as vehicle crashes, assault violence (Scribner et al., 1994, 1995), arrest rates for public drunkenness, misdemeanor and felony drunken-driving, (Rabow and Watts 1982; Watts and Rabow, 1983), violent crimes (Speer et al., 1998; Zhu, 2004). However, making inferences about individual behaviors based on aggregate relationships in ecological studies can be misleading and is widely known as the ecological fallacy (Robinson, 1950). More recent studies have complemented the literature by integrating individual-level data with environmental characteristics. This approach is developing and the findings thus far are mixed. I will examine the relationship between the spatial location of alcohol outlets and problem drinking among the adult population by using mapping techniques and individual-level data. Building on prior research, my study is designed to strengthen the current literature by exploring problem drinking including excess alcohol consumption, heavy drinking episodes, driving after drinking, and riding with a drinking driver by type of alcohol outlets located in various distances from respondent residences. While physical availability of alcohol is a necessary condition for problem drinking, social context may be an additional inducing factor. I conduct sensitivity analyses that differentiate drinking context by location types where social and cultural norms may be encouraging to excess drinking.

Weight Gain Trend across Sociodemographic Groups

Annual deaths attributable to obesity among the U.S. adults are approximately 300,000 (Allison et al., 1999). Different studies have documented that large segments of the American population are either overweight (a body mass index, BMI, over 25) or obese (BMI>=30) and that disparities in overweight and obesity prevalence always exist across population subgroups defined by race/ethnicity, gender, age, or socioeconomic status (Mokdad et al., 2003; National Center for Health Statistics, 2004). While sociodemographic differences in the prevalence of unhealthy weight contribute to health disparities, it is not clear if the current obesity epidemic widens or narrows these disparities. There are plausible hypotheses for widening, maintaining, and narrowing disparities related to unhealthy weight. If broad environmental factors such as suburbanization, increased food availability, and motorization are among the most powerful determinants, affecting all population subgroups, then the whole weight distribution curve would shift to the right. The pattern of weight gain over time in that case would be more uniform than the common belief based on cross-sectional differences. Policy would need to facilitate interventions that seek to not only curb the high prevalence of obesity among subpopulations, but also to stop the increasing weight gain trend of the whole population. The latter is often regarded as the population strategy and can have powerful impacts (Rose, 2001). This study is designed to carefully examine the weight gain trends across sociodemographic groups in the U.S. and to provide input to the debates for effective intervention aimed at curbing the obesity rates.

Food Environments and the Obesity Epidemic

Obesity with its profound effects on individual health and the healthcare system is currently one of the greatest public health concerns in the U.S. Annual national obesity-attributable medical expenditures are estimated at $75 billion, and about one-half of these expenditures are paid by Medicare and Medicaid (Finkelstein et al., 2004).

Researchers are increasingly aware of contextual influences, including the role of the built environment, on the excessive prevalence of obesity (Cunningham and Michael, 2004; Papas et al., 2007). Local food supply is an important aspect of the built environment that has been examined in relation to nearby residents' dietary intakes (Cheadle et al., 1991, 1993; Edmonds et al., 2001), and weight outcomes (Thompson et al. 2004, Taveras et al., 2005; Duffey et al., 2007; Wang et al., 2007). There is a strong link between community characteristics and the location and type of food stores. The general finding is that predominantly minority and racially mixed neighborhoods have less healthy food choices (Morland et al., 2002a; Moore and Roux AV, 2006; Powell et al., 2007).

In my judgment, there are three key limitations in the literature of the food environments and individual health, namely, limited sample data, use of predefined geographical units, and partial focus on one type of food outlets. Several studies attempted to link the geographic distribution of fast food restaurants to neighborhood sociodemographics (Block et al., 1995; Macdonald et al., 2006). However, it remains unclear if the absolute or relative availability of food outlet types in local areas matters when it comes to the consumption decision. Absolute availability refers to the number of an outlet type while relative availability refers to the fraction of all outlet types that are a certain outlet type. There is currently no study that constructs comprehensive measures of retail food environments and links them to individual health behaviors or outcomes.

I explore an emerging opportunity to learn about the relationship between retail food environment and individual body mass index. In its recent study about the food landscape in California, the California Center for Public Health Advocacy found that California as a whole had more than four times as many fast-food restaurants and convenience stores as supermarkets and produce vendors in 2005, yielding a statewide Retail Food Environment Index (RFEI) of 4.18. I examine the relationship between the relative availability of food outlets and individual body mass index by mapping individual-level health data in the California Health Interview Survey 2005 to county-level RFEI. I conduct different statistical procedures to translate the regression results into policy-relevant statistics.

This dissertation seeks to make a contribution to knowledge through a novel empirical approach. I use ArcMap, a Geographical Information System application that facilitates creation and analysis of geographic data, to prepare the analytical data. In each stage, from framing research questions to empirical analyses, effort is made to ensure that research findings are policy-relevant. A number of statistical procedures are employed to translate aggregate statistics into meaningful numbers for the public debates.

The remaining dissertation is organized as follows. In the next chapter, I review the literature that examines the effects of contextual factors on health outcomes, focusing on methodological issues. I will then propose an analytical framework for my dissertation. The four essays will subsequently follow in Chapters 3, 4, 5 and 6. Limitations of the analysis and policy implications from the research findings will be discussed within the respective chapters.

Chapter 2: Literature Review of Neighborhood Studies and Proposed Analytical Framework[1]

The basic premise for neighborhood studies argues that both individual and contextual characteristics affect individual health behaviors and outcomes, and the way contextual factors operates is not reducible to the properties of the individual characteristics themselves (Morenoff and Lynch, 2005). Typical community factors that may influence health include the availability and accessibility of health services, a dearth of infrastructure, the prevalence of prevailing attitudes towards health and health related behaviors, and a lack of social support (Macintyre et al., 1993). As Oakes (2003) argued, it would be surprising to learn that disadvantaged neighborhoods, which have dirtier, less safe, and more stressful environmental conditions than advantaged neighborhoods, did not somehow affect health. Remaining important questions include the magnitude, mechanism, and mutability: how big are the effects, how do they emerge, and how might such information be exploited to improve public health.

The concept of neighborhood effects on health itself is not new, but evidence thereof is far from clear. Issues such as how to define a neighborhood and how to measure neighborhood characteristics have not been resolved thus leaving no consistency of the terminologies such as "neighborhood effect" used in the literature. A number of studies that considered how individual and neighborhood deprivation might influence health found mixed evidence (Stafford and Marmot, 2003). However, what many of those studies truly investigated was the "compositional effect" rather than "contextual effect". Compositional

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[1] The first part of this chapter is based on my co-authored work with Sai Ma: "Truong KD, Ma S. A systematic review of relations between neighborhoods and mental health. Journal of Mental Health Policy and Economics. 2006 Sep; 9(3):137-54".

effects arise from the varying distribution of types of people whose individual characteristics influence their health. In contrast, contextual effects operate where the health experience of an individual depends partly on the area where they live (Curtis and Rees-Jones, 1998). Much of this inconsistency also stems from the different foci of the relevant studies. Roux (2001) noted that the size and definition of the relevant geographic area might vary with regard to the processes through which the area is hypothesized to operate and affect the health outcome being studied (2001). Unfortunately, data are not always available at the desirable resolution. For instance, equating neighborhoods with census tracts can lead to difficulty in evaluating outcomes as census tracts can be too small to meaningfully evaluate characteristics such as crime and poverty in the neighborhoods, but too big for characteristics such as respondents' informal interactions, connections, and alliances with their neighbors. Researchers usually have to depend on predefined administrative geographical units such as zip codes or census tracts at which level data are available, resulting in a mismatch between the process scale and data resolution. The self-selection bias of the data sample and possible interactions between neighborhoods and individual behaviors pose significant challenges to empirical studies that investigate the causal effects of the shared environments.

Measuring Neighborhood Characteristics

Studies to date have examined a wide range of neighborhood characteristics. They are usually measured objectively and transformed into individual variables or composite indices. Sometimes they are subjectively assessed by the respondents themselves. For instance, vandalism, litter or trash, vacant housing, and social support in the form of emotional assistance, and social participation are rated by respondents in a study that link neighborhood disorder to individual depression (Latkin and Curry, 2003).

One of the most common categories of neighborhood characteristics is their sociodemographic structure. For instance, Elliott (2000) examined the relation between socio-economic status and health, both mental and physical, within a stress-process framework. Five indicators - median income, percent of Black residents, percent of households on public assistance, percent of female-headed households, and percent of female-headed households in poverty, were combined into a standardized index. Goldsmith et al. (1998) measured the economic status of neighborhoods by census tract median household income and social dimension by percentage of non-family households, percentage of husband-wife families among all households and ethnic composition. Ostir et al. (2003) measured the percentage of Mexican Americans and the percentage of persons living in households with income below poverty. Reijneveld et al. (1998, 2000) measured area deprivation by mean registered income, percentage of households with income below minimum and unemployment rate.

Focusing on risk factors, another group of studies emphasize neighborhood disadvantages such as crime, instability, and social disorder. Hill and Herman-Stahl (2002) examined the relation between neighborhood safety and parenting among mothers of kindergarten children. Neighborhood safety was independently rated by both interviewers and mothers, and the interviewers completed the Post Visit Inventory (PVI), using a 4-point Likert-type scale. Leventhal & Brooks-Gunn (2003) measured neighborhood physical and social disorder by parental ratings of the level of trash, graffiti, public drinking, public drug use or dealing, and abandoned buildings.

The physical or built environment has increasingly become an important domain of environmental studies. Ewing et al (2002) developed a metropolitan sprawl index that is made of hundreds of individual measures centered around four physical dimensions: residential density, land use mix, degree of centering, and street accessibility. Frank et al. (2005) developed objective measures of the built environment unique to each household's physical location including land-use mix, residential density, and street connectivity. Weich et al. (2002) argued that the way built environment, including housing form, roads, footpaths and other public amenities, affects individual health is remarkably different from that of socioeconomic and demographic characteristics. They used the standardized and validated Built Environment Site Survey Checklist for rating housing area. Items included the predominant form, height and age of housing, number of dwellings and type of access, provision of gardens, use of public space, derelict land, security and distances to local shops and amenities.

Other studies have investigated a mix of neighborhood characteristics varying from poverty to social disorder, demographic composition to residential stability, and crime to informal social ties. White et al. (1987) hypothesized that perceived crime has a negative impact on mental health of women and children. Their crime index was based on responses about 3 types of crime: assaults in the street, robberies in the home, and juvenile vandalism. They further hypothesized that physical quality of the residential environment acted as a conditioning variable in the association between crime and mental health. Good-quality environment was hypothesized to act as a buffer, mitigating the negative impact of perceived crime. Thus, to account for the quality of the environment, neighborhood conditions also included noise and pollution, run-down housing, and poor neighborhood maintenance. The last hypothesis was that the quality of social environment also had a conditioning effect: and a high-quality social environment would buffer the negative effect of perceived crime. Thus they included interactions with neighbors, friends, and relatives, as well as quality of spouse or partner relationships. Ross et al. (2000) included objective measures including neighborhood stability, poverty, and interaction between stability and poverty, and combining them with perceived neighborhood disorder by using the Ross-Mirowsky 15-item scale and informal social ties with neighbors. Silver et al. (2002, 2000) measured neighborhood disadvantage by measures such as percentage of families below poverty line, percentage of female- headed families with children, percentage of households with public assistance income, and unemployment rate. They then captured neighborhood residential mobility by using percentage of rental housing and percentage of 5-year olds who changed address within the last 5 years.

Critiques of the Literature

There are a number of important shortcomings in the way the neighborhoods are conceptualized and measured in the literature. First, the "poverty paradigm" still dominates the literature, focusing mostly on census-based indicators of neighborhood sociodemographics and emphasizing deleterious effects of concentrated poverty on health outcomes. For instance, Giskes et al. (2006) concluded that living in a deprived area seems to reduce the likelihood of quitting smoking, at the same time admitting that the underlying factors associated with living in a deprived area that contributes to lower quitting rates need to be identified. Given the readily available Census data, it is rather simple, but not accurate, to construct some measure of neighborhood poverty at census tract level and examine its relationship with smoking rates or quitting rates or some other health outcomes. Even if some significant relationship is found, it is not clear what policy actions should be taken.

Can one successfully launch a tobacco controlling campaign that aims to reduce neighborhood poverty to cut smoking rates? At the concluding session of a conference I recently attended[2], one of the chairs jokingly yet seriously asked the participants whether it would be the next step to convince community leaders and local authorities that they needed to fix street pavement to cut the extraordinarily high number of cancer cases in the studied communities!

It is not just researchers who should be blamed for confusing findings. That is partially the nature of non-experimental research, which in essence is a type of investigation of phenomena without attempting to change the subject of interest in the process. In contrast to the way clinical scientists work, social scientists most often do not properly observe the "treatment", let alone conducting a social experiment that in some theory produces an outcome of interest. It is perhaps true that street pavement is one of the many steps and events that facilitate people to engage in physical activity. In return it helps people improve their health, and through some biological process also helps reduce the odds of having cancer developed. Unfortunately, often researchers do not observe whether the respondents really want to walk around their neighborhoods or the counterfactual – that they would actually walk around if the pavement were fixed. Even when researchers properly observe the "treatment", competing theories often exist to provide alternative explanations about what actually produce the outcome of interest. There can be unobserved or even unobservable characteristics of the treatment and non-treatment subjects that never can be fully controlled for unless it is a randomized controlled trial. And in non-experimental research, one can always concoct a "story" why some uncontrolled characteristic can contribute to the change in the outcome, making the derived findings biased. A perspective

[2] Centers for Disease Controls - Funded Centers for Population Health and Health Disparities Grantee Meeting, Boston, June 7-8, 2007.

often held by econometricians is that observed outcomes are the result of people's optimizing behavior. When we do not properly understand their complex and behind-the-scene decision making process, interventions based on biased results would be inefficient and even undesirable. This discussion is ultimately related to the issue of causality which I do not intend to elaborate here. My basic argument in this discussion is that when treatment is not properly observed, proxy measures need to be as close and direct to the treatment as possible.

Another issue with neighborhood measures is the use of composite indices. While I do not deny the validity of indices, it is perhaps not only a single contextual factor but several jointly affect a certain health outcome. There are cases (e.g. Ewing and his colleagues' sprawl index) where an index is necessary to meaningfully capture environmental characteristics. These indices usually go through rigorous validation tests. The use of indices also improves statistical efficiency and avoids multicollinearity among single measures. However, there are major disadvantages of using composite indices. First they limit our ability to identify which and how specific neighborhood characteristics contribute to the outcome of interest. As Roosa et al. (2003) pointed out the use of composite indicators can obscure the processes that are at work in determining the health outcome. Second, indices make it difficult to interpret research findings thus limiting policy leverage. A change of some unit in a neighborhood poverty index often offers little information what that means unless extra effort is made. The task of translating and turning research findings into policy intervention becomes much more difficult when the measure of health outcome is also a composite index. Though it is almost never true that the decision to allocate public resources is based on the equality of the equation with the expected marginal benefit on one hand and marginal cost on the other, it is still of policy importance to provide guidance and indication on the estimated cost of a social problem and the expected benefit of an intervention. When it is necessary to use an index, efforts need to be made to facilitate interpretation of research findings.

Lastly, let me turn to one important technical aspect that in my opinion deserves special attention for improvements: the definition of neighborhoods. Defined neighborhoods need to better reflect the actual neighborhoods. Most studies I have examined operationally adopt a "convenient" definition of neighborhoods, whether they are electoral wards, school districts, zip codes or census tracts. With regard to appropriate concept, definition and construct of neighborhoods, there are numerous studies that laid the foundation for and developed this work further (e.g. Park, 1916; Burgess and Park, 1967; Suttles, 1972; Morenoff and Lynch, 2005). My primary argument here is that the geographical boundaries must match with the *nature* of the contextual characteristics and the health behavior or outcome of interest. Figure 2.1 presents a graphic illustration of the multilevel and multidimensional nature of contextual factors that can affect health outcomes through behaviors. The geographies of contextual factors obviously vary by their nature. At the highest level, characteristics like form of government (e.g. democratic vs. totalitarian), climate (e.g. tropical vs. maritime), terrain (e.g. plain vs. mountainous) can all affect individual health behaviors. Next in this hierarchical structure are state-level factors such as welfare policy, employer-sponsored health insurance stature, and state mental health parity laws. Following are such factors that vary from the county/metropolitan (e.g. pollution and unemployment rates) to city level (e.g. street design, recreational facilities, parks), and from community (e.g. faith-based organizations and crime), to neighborhood level (e.g. sociodemographics and social ties with neighbors). In principle, data resolution, the geographic level at which the data are analyzed, needs to reflect the process scales - the geographic range of a contextual factor that is relevant for the outcomes of interest. If researchers believe that collective efficacy, measured by the willingness and readiness of a neighborhood to act together to solve a problem, operates at a scale below community factors, then it would be essential to set up collective efficacy data at its appropriate resolution, certainly finer that that of community-level data. One would say that the level of analytic data for contextual factors of course must be set up in accordance with their nature. Unfortunately, that is often not the case due to unavailability of data.

After having the above said, I should emphasize that there are certain type of characteristics that administrative units such as census tracts may be good proxies for neighborhoods. The census tract definition is supported by the 1994 National Institutes of Health conference on social inequalities, which recommended the use of census data to provide neighborhood measures of *socioeconomic characteristics* (Moss and Krieger, 1995). However, little efforts have been made in testing and getting closer to the relevant definition of neighborhoods. There is a need to develop varying data resolutions for certain contextual factors. For instance, when examining how crime in neighborhood affects mental health, one should consider measures of crime episodes that occur within varying distances from the respondents' home. There is no reason to believe that only crime episodes within census tracts or zip codes matter. Empirical work becomes essentially important in understanding how such contextual factors operate.

Another technical issue that has been paid less attention to is what and how characteristics of contextual factors are measured. Does average or median household income of a neighborhood reflect what we actually want to capture? Is it the relative or absolute household income that matters? Equally important question is how sensitive are these measures to a modified definition of neighborhoods? Answers to some of these typical questions can be found in a novel empirical approach.

Proposed Analytical Framework

In this section, I would like to present an analytical framework that is designed to overcome some shortcomings of the literature discussed previously. I will devote a large part of my efforts to the construction of a relevant neighborhood environment and appropriate data resolution.

Let me use a general setup for the analytic framework: alcohol environments and adolescent drinking. There are different explanations for why the environment in which adolescents live, study, play, and interact can affect their decision to drink: culture, minimum age drinking laws, law enforcement, television, alcohol advertising, and peer pressure, just to name a few. A number of studies have examined the link between physical availability of alcohol in the neighborhoods and adolescent drinking (Wagenaar et al., 1993; Forster et al., 1994, 1995; Rhee et al., 2003). Based on the previous literature, I take the initial proposition that the physical availability of alcohol in the neighborhoods can affect adolescent drinking.

The first step to examine the above hypothesis is to construct measures of alcohol availability in the neighborhoods. One obvious way to go is to measure commercial sources of alcohol in conventional neighborhoods such as census tracts or zip codes. In fact, many studies have taken this approach (Speer et al., 1998; Gorman and Speer, 1997; Scribner et al., 1994; LaVeist and Wallace, 2000; Zhu, 2004; Romley et al., 2007). So what exactly is the problem of using the conventional definition of neighborhood in this case?

Figure 2.2 shows the spatial location of off-sale beer and wine stores and census tracts in a selected area of West Los Angeles. There are a number of important observations from Figure 2.2. First, the size of census tracts varies greatly. In fact, California has 7,050 census tracts with the median area of 0.77 square miles. While the boundary of a typical census tract in an urban area is within walking distance, rural tracts in California can cover an area of over 1,000 square miles. Even within Los Angeles County, the size of census tracts can range from 0.04 square miles to 322 square miles. Using census tracts to approximate neighborhoods in general and to measure alcohol sales in neighborhoods in particular is not accurate.

Second, alcohol outlets are often located on major streets that typically demarcate census tracts. Figure 2.2 shows that the majority of alcohol outlets are located on the tract boundaries. If we zoom in close enough, we will see that these outlets are located on one side of the tracts. A measure of alcohol outlets that are located exclusively within census tracts seriously under-estimates access to commercial alcohol sources. People living in adjacent tracts can just cross the street to get to several alcohol retailers that would have been ignored in a regression analysis in which the unit of analysis for alcohol outlets is census tract. Third, census tracts are *mutually exclusive* geographical units. Any given alcohol outlet is located within one and only one census tract. Or in other words, there is no overlap in the "shopping zone". Using mutually exclusive geographical units happens to impose an unrealistic assumption. Last but not least, different alcohol-related problems (e.g. binge drinking, driving after drinking) can happen at different drinking locations at varying distances from home. Having only one fixed data resolution imposes another unreasonable assumption: People buy their alcoholic drinks from alcohol outlets within their census tract only. That is certainly not true for individuals living in small census tracts.

When we are talking about the physical availability of alcohol in the neighborhood environment, it is important to recognize that we are not really thinking about the conventional neighborhood. It is practically about the spatial accessibility and physical area within which alcohol retailers are located. To capture the idea of environmental determinants of drinking behaviors, it is necessary to deal with two concepts of neighborhoods. The first one is the "physical neighborhood" from which one buys his or her alcoholic beverage. This "physical neighborhood" does not have to strictly follow the standard sociological concept of neighborhoods. Empirical work rather than theory seems to play a stronger role in identifying the appropriate boundaries for the physical neighborhood. The second one we should also be dealing with is conventional neighborhood, whose sociodemographic structure shares common attributes and in some theory can have an independent effect on adolescents' drinking.

To operationally account for two types of neighborhoods, I propose the following regression model.

$$Y_{i,n,a} = \beta_0 + X_{i,n,a}*\beta_1 + N_n*\beta_2 + A_a*\beta_3 + \varepsilon_{i,n,a}$$

where

$Y_{i,n,a}$ represents a drinking behavior by adolescent i living in neighborhood n surrounded by alcohol environment a;

$X_{i,n,a}$ represents a vector of adolescent i's individual and family characteristics;

N_n represents a vector of the sociodemographics of conventional neighborhood n

A_a represents a vector of the alcohol retailers in physical neighborhood a

$\varepsilon_{i,n,a}$ is an individual specific random error term with mean zero and variance σ^2.

Two hypotheses guide the empirical work. First, commercial availability of alcohol affects adolescent drinking behavior and the effect diminishes with distance. Second, neighborhood socioeconomic structural characteristics within census tracts are associated with individual drinking behaviors. Unfavorable characteristics such as high unemployment rates, poverty rates, and low education are hypothesized to be positively associated with problem drinking.

Note that the boundaries of the physical neighborhood and conventional neighborhood of the same adolescent are not necessarily identical but must overlap at their centroid. The reason for being so will become clear in next paragraph. The remaining question is how we create the physical neighborhood, if not using the conventional neighborhood, to determine how many and what type of alcohol retailers located within it.

The answer to this question is one of the major areas to which my dissertation is devoted. ArcMap, a Geographical Information System application, is a useful tool to create, interact, symbolize, and analyze geographic data. Figure 2.3 shows a map of California with the spatial distribution of alcohol retailers, which are represented by the dark red dots. At this scale (about 1: 6,000,000), the map gives us an impression about the concentration of alcohol sales in urban areas but no feeling about their location vis a vis residential neighborhoods. Figure 2.4 shows the same map but scales down to the Bay area where the locational pattern of alcohol outlets starts to take shape. They appear to be concentrated in populated areas. For the analysis of neighborhood environments, we certainly need maps at much finer scale. Figure 2.5 presents such a map in which I created circular buffers around residence of each respondent in a selected area of West Los Angeles. People's access to commercial alcohol sources clearly depends on their home location relative to alcohol outlets' location. The accessibility is unique for each individual depending on his or her location. The buffers areas are of the same size and shape, and thus avoiding the problem of inconsistent size and arbitrary shape of census tracts. Two sets of buffers, 0.1 mile and 0.3 mile radius, are created for illustration purpose, but in fact I can create as many buffers as necessary to identify the most appropriate data resolution for this particular contextual factor. I will argue in detail in chapters 3 and 4 that it is important to examine a range of geographies to understand what distance to home is the most critical when it comes to linking problem drinking to alcohol sales. By doing so, the research question becomes more policy-relevant. Instead of trying to regulate alcohol sales in the neighborhoods, which have a vague meaning in a regulation context, a more concrete regulation measure can be the minimum distance from an alcohol outlet to the closest residential home.

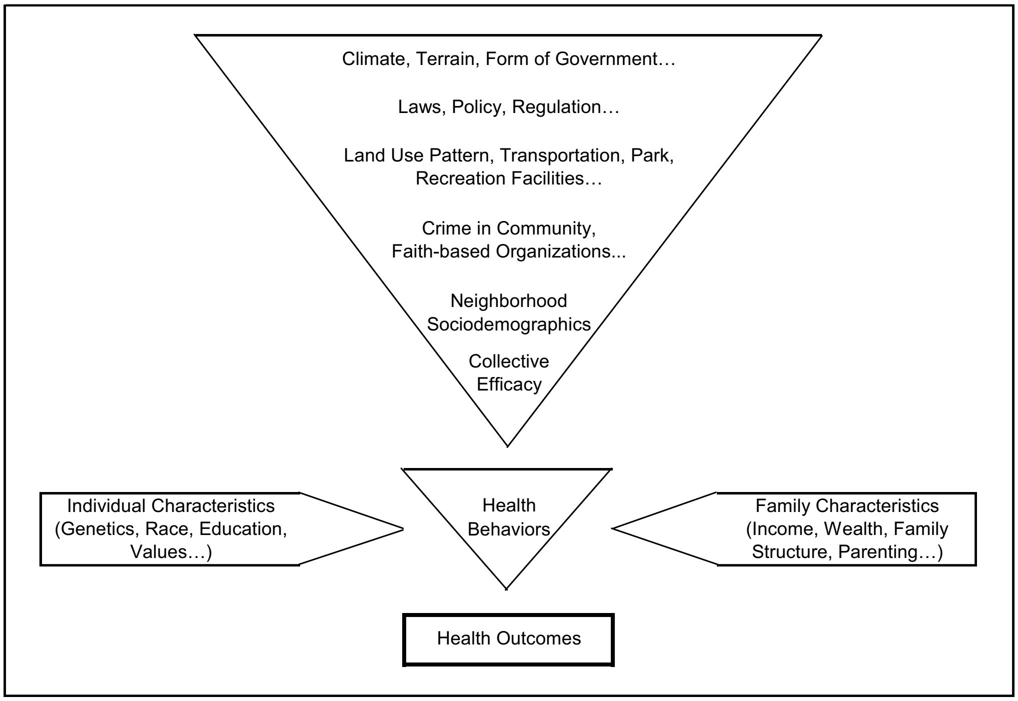
To create maps as the one in Figure 2.5, three major tasks were performed: geo-coding data, constructing geographic units (GUs), and measuring alcohol outlets in each GU. Geo-coding is a process of assigning geographic identifiers such as street address to map features and other data records. After converting the street address of alcohol outlets into geographical points defined by their latitude and longitude, they are placed on a base map for merging with respondent data later. The number of alcohol outlets located within each GU is calculated by spatially joining the GUs with the respondent data. At least two pieces of information are needed to use the buffer approach: location of alcohol outlets and location of respondents. Obtaining information on alcohol outlets is not difficult but having access to information on the exact location of respondents is typically unrealistic. Human subject requirements restrict the release and use of geographic identifiers. If location codes are available at all, they may be as crude as a state or metropolitan area identifier. One data set I use has access to the exact respondents' home location and the other has census tract locations for the respondents' home location.

What can we do if census tract, instead of home address, is the finest available geographical information? A second alternative concept of the alcohol environment I will use is this dissertation is the buffers around census tracts. Figure 2.6 shows two buffers, 0.1

mile and 0.3 mile, extended from the census tract boundaries. Buffers of a given census tract overlap with buffers of the adjacent census tracts, and therefore, the same outlets can be counted in multiple buffers (i.e. creating overlap in shopping zone). Multiple buffers also help properly model drinking behaviors that can occur in varying geographies. And last but not least, it eliminates the peculiar coincidence of having many outlets located on the boundaries of GUs.

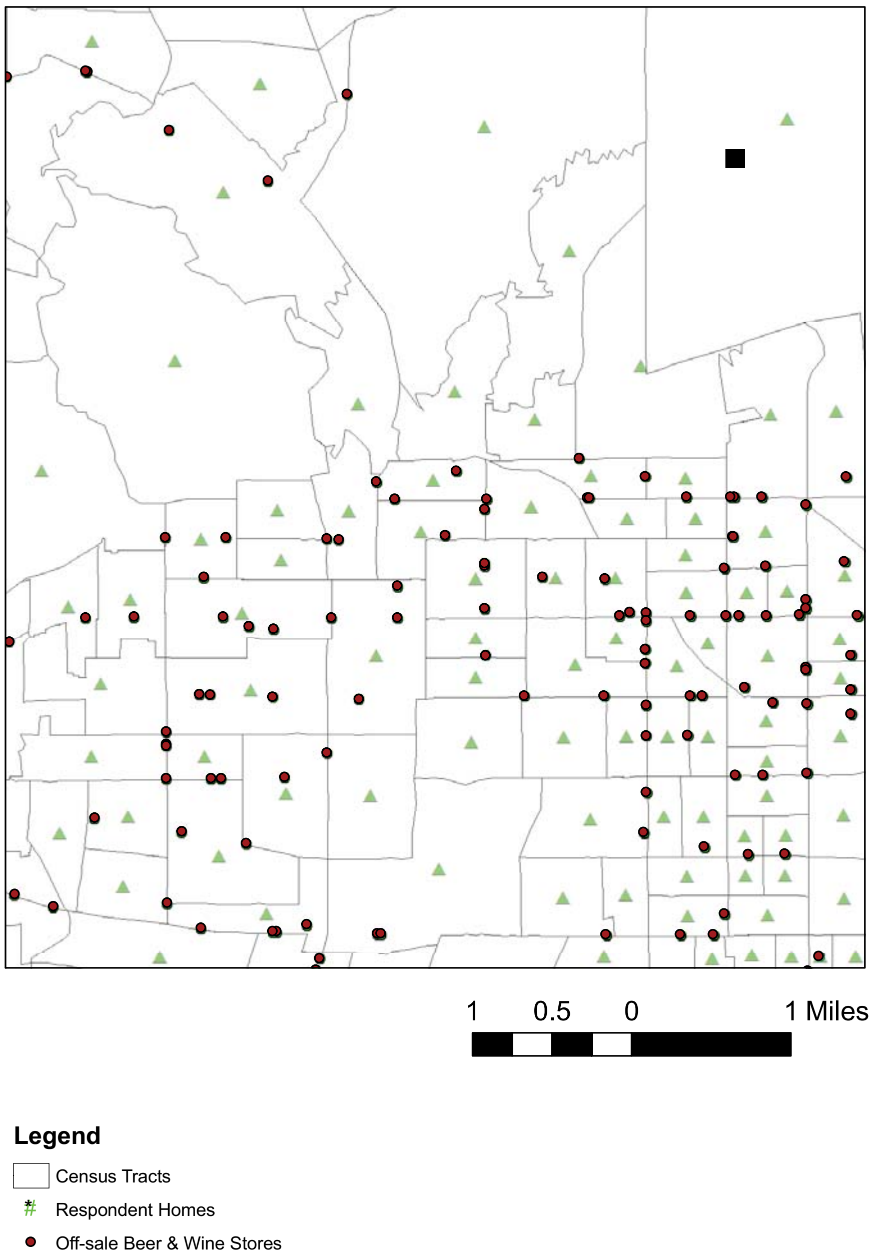
My detailed analytic plan will be presented in the respective chapters. The conceptual framework discussed above provides an overall description of the methodologies and technical areas that my dissertation is sought to make a contribution. It also showcases how research questions can be framed and explored in a more policy-relevant fashion with the help of a novel empirical approach.

Figure 2.1: A Schematic Illustration of Environmental, Family, and Individual Determinants of Health Behaviors and Outcomes



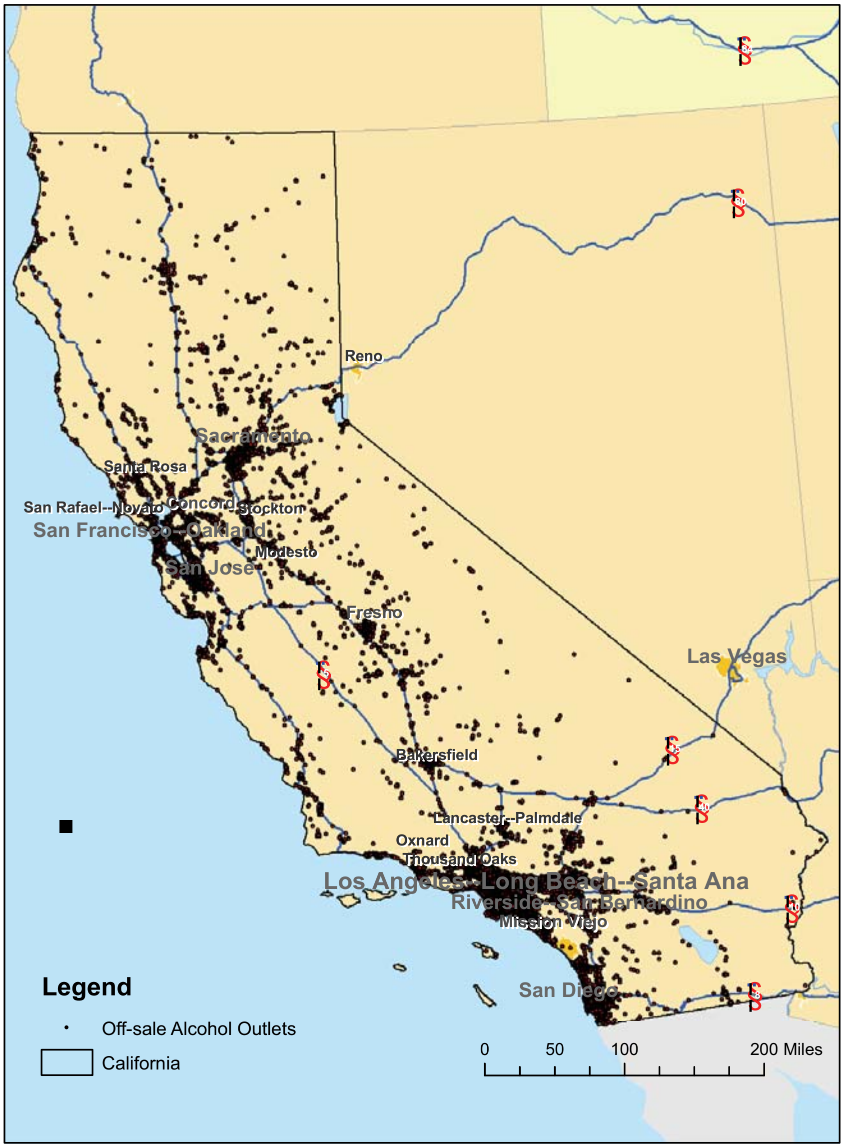
Source: Author's own construction

Figure 2.2: Selected Census Tracts and Off-sale Beer & Wine Stores in West Los Angeles



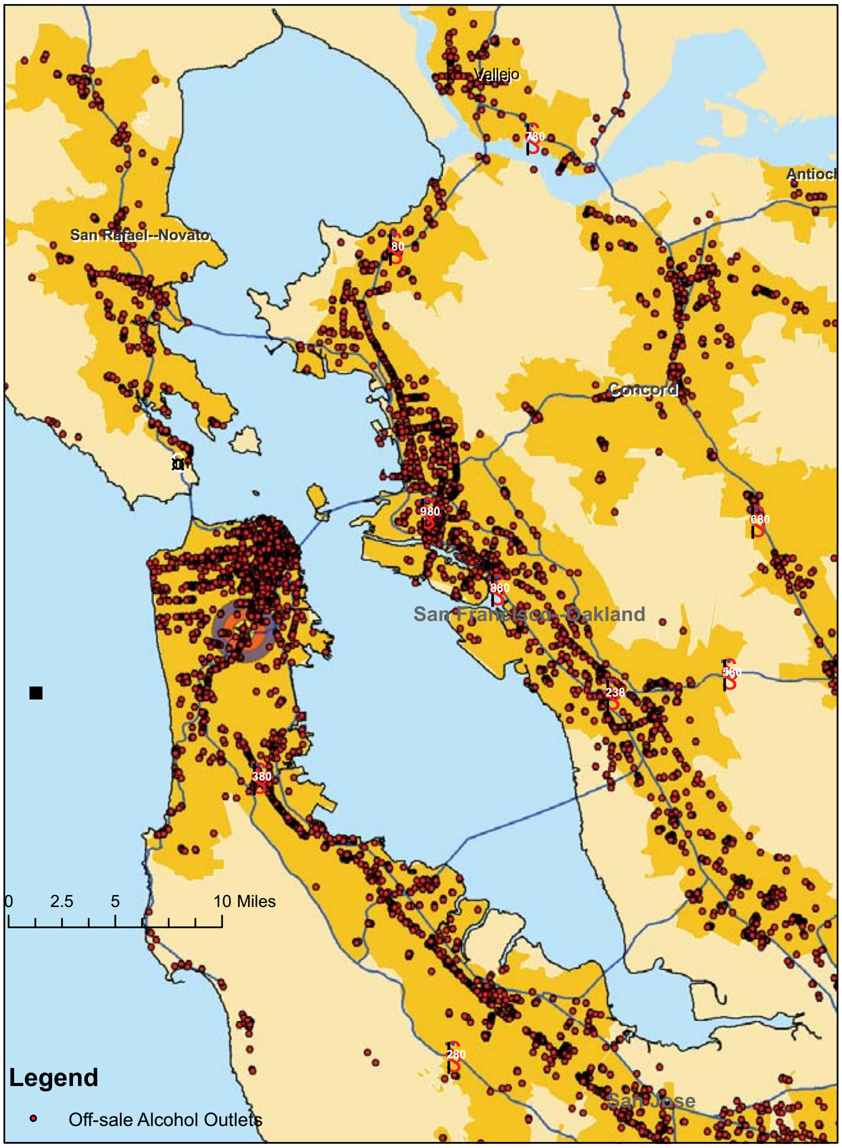
Source: Author's construction based on data from California Department of Alcoholic Beverage Control

Figure 2.3: An Overview of Spatial Distribution of Off-sale Alcohol Outlets in California



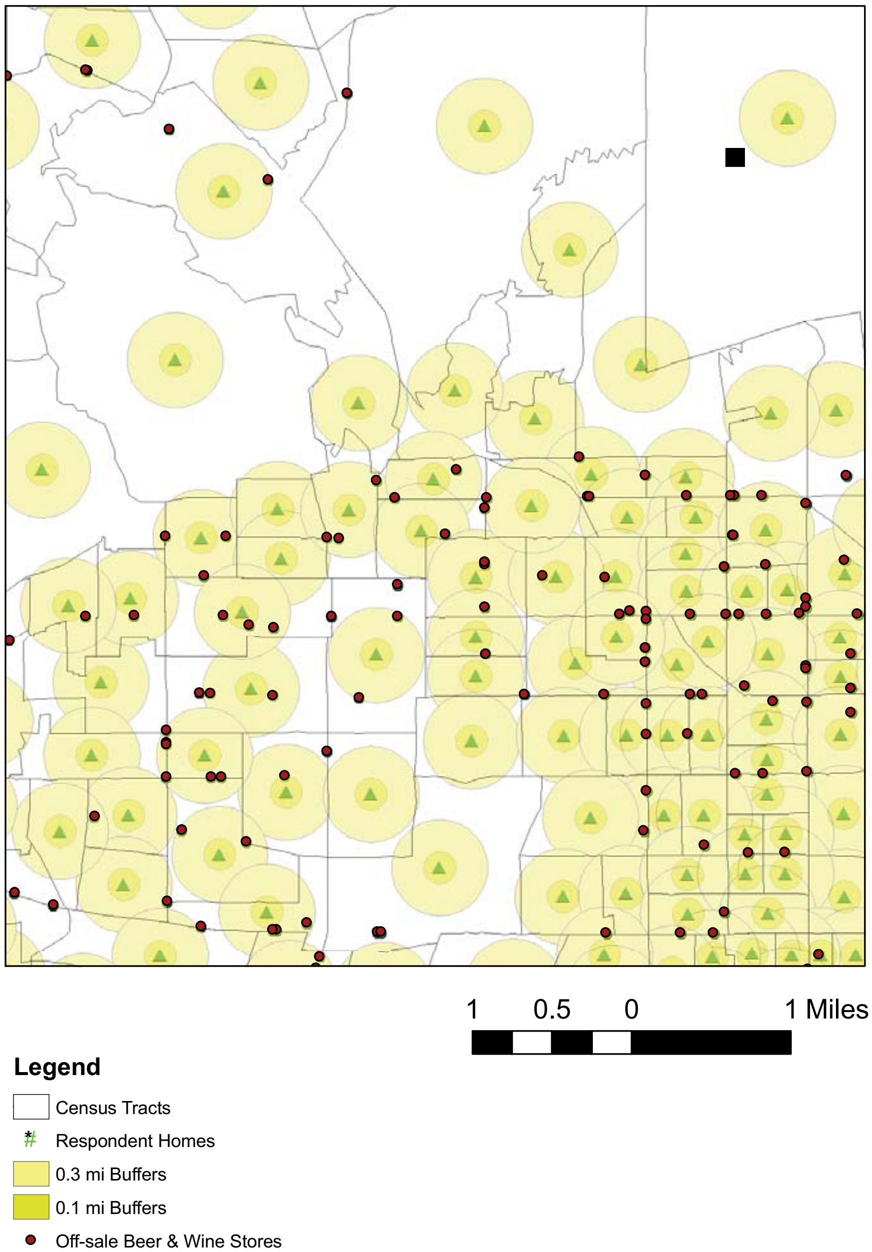
Source: Author's construction based on data from California Department of Alcoholic Beverage Control

Figure 2.4: An Overview of Spatial Distribution of Off-sale Alcohol Outlets in the Bay Area, California



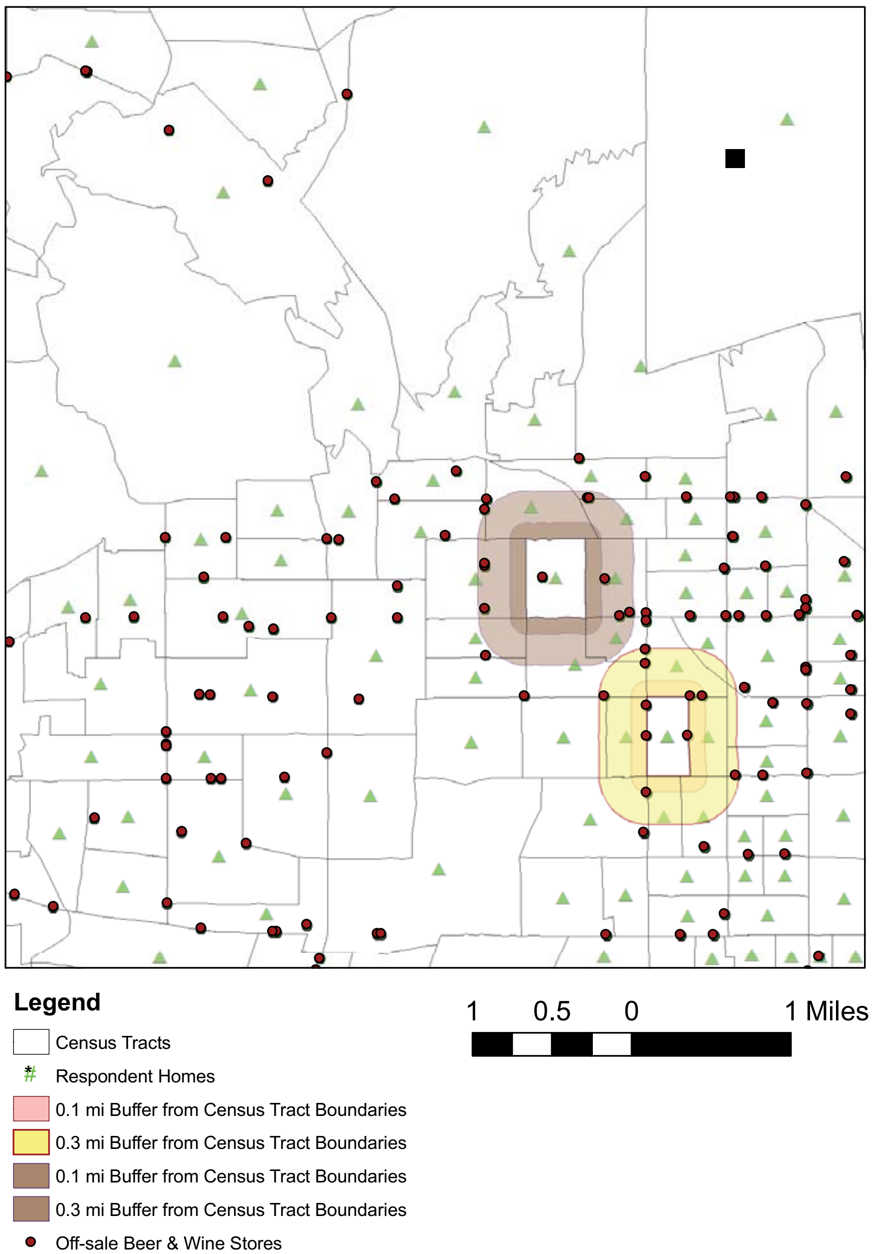
Source: Author's construction based on data from California Department of Alcoholic Beverage Control

Figure 2.5: Selected Census Tracts, Buffers around Individual Homes, and Off-sale Beer & Wine Stores in West Los Angeles



Source: Author's construction based on data from California Department of Alcoholic Beverage Control

Figure 2.6: Selected Census Tracts, Buffers around Tracts, and Off-sale Beer & Wine Stores in West Los Angeles



Source: Author's construction based on data from California Department of Alcoholic Beverage Control

Chapter 3: Alcohol Environments: Disparities in Exposure and Adolescent Drinking in California

Abstract

Objectives: To investigate sociodemographic disparities in alcohol environments and their relationship with adolescent drinking.

Methods: Alcoholic Beverage Control license data are mapped to California Health Interview Survey data. ArcMap is used to generate buffers with varying radii centered at 14,595 residences of households with children ages 0-17, and measure alcohol sales in each buffer. Logistic regression is used to discern effects of alcohol outlets located within these buffers from adolescent individual and family characteristics, caregiver drinking behavior, and neighborhood sociodemographics.

Results: Alcohol availability, measured by mean and median number of licenses, is significantly higher around residences of minority and lower-income families. Adolescent binge drinking and driving after drinking are significantly associated with alcohol sales within 0.5 miles from homes. Counterfactual simulation shows that if mean alcohol outlets in neighborhoods changed from that of the highest to the lowest-income quartile households, prevalence of binge drinking would fall from 6.4% to 5.6%, and driving after drinking would decrease from 7.9% to 5.9%.

Conclusions: As alcohol outlets are concentrated in disadvantaged neighborhoods, disparities in health risks are worsened by alcohol sales' direct effects on problem drinking and indirect effects such as drunk driving.

INTRODUCTION

Despite all the federal, state, and local interventions, underage drinking remains highly prevalent: About 73 percent of students have consumed more than just a few sips of alcohol by the end of high school (Johnston et al., 2007). There are many health and social problems associated with youth alcohol use, particularly with heavy alcohol consumption, including alcohol-related motor vehicle crashes (Smith et al. 1999; National Highway Traffic Safety Administration 2003), suicide and homicide (Centers for Disease Control and Prevention 2004), risky sexual behaviors (Cooper et al., 1994; Cooper and Orcutt, 1997), assault and rapes (Hingson et al., 2005), and potential brain impairment (Sher, 2006; Brown et al. 2000; Brown and Tapert 2004; Crew et al., 2000). These problems generate substantial societal costs (Levy et al., 1999). Drinking at an earlier age also increases the risk of addiction and other alcohol-related problems in adulthood (Robin, 1978; Gonzalez, 1989; McGue, 2001). In early 2007, the Surgeon General issued the "Call to Action to Prevent and Reduce Underage Drinking", which emphasized understanding and taking into account the dynamic developmental processes of adolescence, role of individual characteristics, and the influence of environments in the adolescent's decision to drink (U.S. Department of Health and Human Services, 2007).

Underage drinkers obtain alcoholic beverages from a variety of sources including parents' stocks, friends, parties, and beginning in teenage years, from commercial sources (Wagenaar et al., 1993). The likelihood that outlets sell alcoholic beverages to persons under the legal drinking age is quite high. Without age identification, buyers who appeared to be under the legal drinking age successfully purchased beer in about 50% of attempts and 75% of the outlets sold beer to buyers at least once in two attempts (Forster et al., 1994, 1995).

Sales to minors were significantly and positively related to the percentage of Hispanic residents and greater neighborhood population density (Freisthler et al., 2003).

If adolescents can easily obtain alcohol from commercial sources, neighborhood outlets are likely to play an important role in underage drinking. Rhee et al. (2003) argues that the environment plays a greater role in the initiation of alcohol use whereas genes are more important for determining alcohol dependence. Perceived alcohol availability was significantly associated with higher levels of alcohol consumption for males and drinking in a public location for females (Jones-Webb et al., 1997a,b). City-level alcohol outlet density measures were associated with both adolescent drinking and driving and riding with a drinking driver (Treno et al., 2003).

Differential alcohol environments may exacerbate health disparities across sociodemographic groups. In Baltimore, LaVeist and Wallace (2000) found substantially more liquor stores per capita in both low-income and predominantly black census tracts. Similarly, Gorman and Speer (1997) found retail liquor outlets abundantly located in poor and minority neighborhoods within one economically disadvantaged midsized city in New Jersey. LaVeist and Wallace used census tracts as unit of analysis but covered only a single city, while Romley et al. covered all urban areas in the US at a cruder data resolution. Only one published national study exists to our knowledge which reported that zip codes with a higher percentage of Blacks had higher densities of liquor stores, and that the density of liquor stores was greater among non-Whites than Whites in lower-income areas for both adults and youths (Romley et al., 2007). Urban zip codes, having a mean land area of 40.1 square miles and mean population of 21,920 persons, are arguably too large to be a measure of a neighborhood (Romley et al., 2007) and even census tracts may be too large.

This study covers the whole state of California while focusing on small areas around individual homes. We are not constrained by predefined administrative geographic units, but create circular areas ranging from 0.1 mile (528 feet) to 2.0 miles from each respondent's residence to study if the proximity of commercial alcohol outlets plays a role in adolescent drinking.

METHODS

Data

Data on alcohol outlets come from the California Department of Alcoholic Beverage Control (ABC) database, which includes information on the address and license type of all alcohol retailers in the state. We classify the main retail license types into two groups: off-sale (for consumption elsewhere) and on-sale (for consumption on business premises). In 2003, California had 30,650 active on-sale licenses and 21,836 active off-sale licenses.

The California Health Interview Survey (CHIS) is a computer assisted telephone interview survey which uses a two-stage, geographically stratified random-digit-dial sample design. Using a two-stage, geographically stratified random-digit-dial sample design, the survey is representative of the state's non-institutionalized population living in households. CHIS interviews one adult in each household and addresses of respondents are geocoded. In households with adolescents and children, CHIS attempts to interview one adolescent ages 12-17 and to obtain information for one child under age 12 by interviewing the adult who is most knowledgeable about the child. More information on the methodology of CHIS is available at http://www.chis.ucla.edu/.

The CHIS 2003 survey includes 42,044 adults, 4,010 adolescents, and 8,526 children. We exclude 3,679 households in rural areas because characteristics of rural areas are very different and unlikely to be have comparable neighborhood environments. We then focus on 14,595 households with children and adolescents ages 0-17 for the analysis of alcohol environments and 3,660 adolescents for the analysis of adolescent drinking.

Measures of Alcohol Environments

Our measures of alcohol environments are based on circular buffers around residences. We first construct buffers with radii of 0.1 mile, 0.3 mile and 0.5 mile using ArcMap version 9.1 (these circles are overlapping). Alcohol outlets located within these buffers may be the most problematic because of their close proximity to residences. A distance of 0.5 mile is a little more than 10 minute walk (Pikora et al., 2002) and easily within the reach of adolescents who do not drive. In California, retail licenses are not typically approved within 100 feet of a residence or within 600 feet of schools, public playgrounds and nonprofit youth facilities, but proximity itself is not sufficient to deny the license (Department of Alcoholic Beverage Control, 2007). As residents of more advantaged neighborhoods are more likely to resist having alcohol outlets located close to the residence than residents of less advantaged neighborhoods, it is possible that there are inequities even at scales much smaller than census tracts. To consider the impact of outlets beyond walking distance, we construct circular bands that are between 0.5 and 1.0 mile and between 1.0 and 2.0 miles away from the respondents' residence (these two larger bands and the 0.5 mile circle are mutually exclusive). We map the business locations of ABC license data to the constructed buffers around each household. Within each buffer we calculate the number of on-sale and off-sale licenses.

Previous research focused on density measures such as the number of establishments per city, per resident or per roadway miles (Scribner et al., 1994; Speer et al., 1998; Zhu, 2004; Romley et al., 2007). We do not normalize outlet measures in such ways and instead focus on alcohol sales around *individual* residences. Conceptually, the raw count of alcohol outlets in each buffer is preferable to outlet density measures. A person may live close to outlets, yet the density of outlets may be almost zero if the area (i.e. the denominator) is largely desert or mountainous. Similarly, in densely populated urban areas, the population definition may show low densities even when most residents live within walking distance of an alcohol outlet.

Statistical Methods

Sociodemographic Disparities in Alcohol Environments

We compare the mean and median number of alcohol outlets (total, on-sales and off-sales, respectively) across race/ethnicity groups (non-Hispanic White, non-Hispanic Black, Hispanic, Asian/Pacific Islander, and other races) and income groups (incomes quartiles derived from self-reported total household annual income before tax). We then stratify by both race and income. We also use a Poisson regression model with number of outlets as the dependent variable and race/ethnicity and income groups as the explanatory variables. A sketch of the model is below.

$$O_i = \alpha_1 + \alpha_2 * R_i + I_i * \alpha_3 + + \varepsilon_i \qquad (1)$$

where

O_i represents the number of alcohol outlets in respondent i's neighborhood;

R_i represents a vector of race/ethnicity (non-Hispanic White is reference group)

I_i represents a vector of income groups (lowest income is reference group)

ε_i is the random error term, assumed to be normally distributed $N(0,\sigma^2)$;

$\alpha_{1,}\ \alpha_2$ and α_3 are a vector of the coefficients to be estimated.

Model (1) is run separately for each definition of the dependent variable O_i (total, on-sale, off-sales) in each geographical unit (0.1 mile radii, 0.3 mile radii, 0.5 mile radii, 0.5 mile - 1.0 mile band, and 1.0 mile - 2.0 mile band)

Alcohol Sales and Adolescent Drinking:

Using a logistic regression model, we examine three dichotomous dependent variables for adolescent drinking: at least one alcoholic drink in the past 30 days, at least one heavy drinking episode (5 drinks or more per occasion and also referred to as binge drinking) in the past 30 days, and ever driving after drinking in the past 30 days. There is evidence of sufficiently high reliability and validity of early adolescents' survey self-reports, particularly of alcohol consumption and alcohol-related problems occurring with low base rates (Smith et al., 1995). Self-reported adolescent drinking amount seems reasonably reliable and valid both on a population and individual level (Lintonen et al., 2004). The analytic CHIS data for this analysis includes adolescents ages 12-17.

The primary explanatory variables are the number of outlets within the 0.5 mile radius circle, in the 0.5 mile -1.0 mile band, and in the 1.0 mile-2.0 mile band. Additional explanatory variables include adolescents' characteristics (gender, age, race, work for pay in the past 12 months, current smoker, marijuana use in the past 30 days), family characteristics (household income, parent's education, parents' marital status), parent drinking behavior (indicators whether parent/guardian self-reported any heavy drinking episode – defined as 5 drinks or more per occasion in the past 30 days, and excess drinking – defined as consumed more than 60 drinks per month), and neighborhood sociodemographics (census tract total population, tract median household income, percent of White population, and percent of Black population; data extracted from US Census 2000).

For each dependent variable, we estimate the predictive power of the total number of licenses, only off-sale licenses and only on-sale licenses. We distinguish between off-sale licenses and on-sale licenses because the underlying process for youth to illegally obtain alcoholic beverages from off-sale sources (like super markets and liquor stores) is likely to differ from that of on-sale sources (like restaurants, bars, and taverns). All regression models use robust standard errors to correct for heteroskedasticity and are weighted to control for differential sampling rates within geographic stratum and race/ethnicity groups.

We use the estimated odd ratios of the logistic regressions in a counterfactual simulation where adolescents are exposed to different levels of alcohol availability in their neighborhoods. The resulting prevalence of drinking behaviors is then estimated accordingly.

RESULTS

Disparities in Alcohol Environments

Table 3.1 provides descriptive statistics of key sociodemographic characteristics of households with children ages 0-17, as well as adolescent drinking and other risky behaviors. The sample is divided into four quartiles of total gross annual household income which are: less than $24,000, between $24,000 and $50,000, between $50,000 and $90,000, and more than $90,000. 10.8% of non-Hispanic Whites belong to the bottom income quartile as compared to 32.0% of non-Hispanic Blacks, 50.4% of Hispanics, 20.8% of Asian/Pacific Islanders, and 32.9% of other races. In contrast, 36.0% of non-Hispanic Whites, 15.1% of non-Hispanic Blacks, 4.7% of Hispanic, 29.1% of Asian/Pacific Islander, and 13.2% of other races are in the top income quartile.

The average age of adolescents in the sample is 14.3 years and 35.1% of them reported ever having more than just a few sips of alcoholic. Fifteen percent reported having at least 1 drink, and 5.6% having at least one heavy drinking episode in the past 30 days. 5.0% report that they currently smoke (ever smoked cigarettes regularly and at least 1 cigarette a day in the past 30 days) and 5.0% report marijuana use in the past 30 days. Of those aged 16 or 17 who have ever consumed alcohol, 6.0% report ever driving after drinking.

Stratified by income and race/ethnicity, Table 3.2 shows the mean number of alcohol outlets within different sized buffers surrounding households with children ages 0-17. Panel A shows that compared to non-Hispanic Whites, people of other race/ethnicity groups are surrounded by more alcohol outlets regardless of the size of the buffer. For instance, within 0.1 mile, there is on average 0.21 outlets around White residences compared to 0.24, 0.39, and 0.33 outlets around residences of Black, Hispanic and Asian, respectively (differences are statistically significant at 0.1% level). This location pattern is true even within an income group. Panel B shows that within the lowest income quartile, Black, Hispanic, and Asian/Pacific Islander people are significantly more exposed to alcohol sales in their neighborhood as compared to Whites. Similarly, panels C, D, E, F, G and H show the same distribution pattern across income groups for all races and within each race. We obtained the same results consistently in a sensitivity analysis using the median number of outlets, off-sales and on sales separately, and running Poisson regression models with income and race/ethnicity as predictors of alcohol outlets. The regression results are reported in Table 3.4.

Alcohol Sales and Adolescent Drinking

In the first logistic regression model (not reported in the Tables) with the total number of alcohol outlets as the key explanatory variable, we find that alcohol sales within 0.5 mile from homes are significantly associated with adolescent binge drinking ($p < 0.05$) and driving after drinking ($p < 0.001$). Alcohol outlets located further away appear to have no relationship with any measures of adolescent drinking. In the second model, we split the total number of outlets into off-sales and on-sales, and the regression results are reported in Table 3.5. As shown in column B, off-sale outlets and on-sale outlets within 0.5 miles are independently and significantly associated with binge drinking after taking into account adolescents' individual and family characteristics, parent/guardian's drinking behavior, and neighborhood sociodemographics ($p<0.05$). A priori we thought it was more likely that driving after drinking to be associated with off-sales for adolescents (in contrast to adults) because on-sale establishments would be less likely to sell to underage drinkers. However, we find that on-sales, not off-sales are significantly associated with driving after drinking as shown in column C. Statistical power can be an issue here because there are much few adolescents with a driving licenses. In a sensitivity analysis, we exclude license types 42 (on-sale beer & wine public premises) and 48 (on-sale general public premises), which do not allow minors on premises and make up 6.2% of the on-sale category. Our regression results do not change in this sensitivity analysis.

The null finding between alcohol outlets and at least one drink in the past 30 days is surprising. One possible explanation is that this level of consumption can occur in a context where adolescents can get alcoholic drinks from their parents' stock. In contrast, binge drinking - often taking place at parties or within a group of friends, requires larger quantities of alcohol that are most likely to be obtained from commercial sources.

An estimated odds ratio of 1.026 (effect of off-sale outlets within 0.5 mile on binge drinking) may appear small, but it is quite substantial because the explanatory variable is a raw count of the alcohol outlets within the 0.5 mile area. Given the base binge drinking rate of 5.6% among all adolescents *in the past 30 days*, that odds ratio is translated into an increase of 0.1 percentage point for a single additional alcohol outlet. Note that the average difference of alcohol outlets located within the 0.5 mile area between the bottom and top income quartile is 4.2 while the average difference between Asian and White households is 6.0. To simulate the effects of disparities in alcohol environments, we predict drinking outcomes resulting from changing the alcohol environments for every adolescent in the sample from one level to another. As reported in Table 3.6 (using the first model with all licenses as key explanatory variables for the simulation), if every adolescent lived in neighborhoods that had the same average number of alcohol outlets as that around Asian households, the prevalence of adolescent binge drinking and driving after drinking would be 6.4% and 7.9%, respectively. Similarly, if all adolescents were exposed to the same average number of alcohol outlets as that around White households, the corresponding statistics would be 5.6% and 6.0%. A reduction of binge drinking from 6.4% to 5.6% (i.e. falling by 12.3%) and a drop of driving after drinking from 7.9% to 6.0% (i.e. falling by 24.8%) are indeed substantial. Table 3.6 also shows the simulation results corresponding to income quartiles and the two groups exposed to the most and least of alcohol sales (Asian in the bottom income quartile and White in top income quartile).

Other significant explanatory variables include age, current smoker, and marijuana use in the past 30 days (significantly and positively associated with adolescent drinking). Girls are less likely to be engaged in binge drinking, and Asian and Black adolescents are less likely to have any drink. Those from households with higher income are more likely to engage in driving after drinking. This is perhaps due to an income effect that is related to the availability of automobile and ability to drive (including driving license and car insurance) because income is not associated with the other two measures of adolescent drinking. Parent/guardian's problem drinking behavior does not independently predict teen drinking and socio-demographics in the census tract do not appear to play a role either.

DISCUSSION

Our study shows consistent evidence of sociodemographic disparities in alcohol environments and confirms findings from previous studies (Romley et al., 2007; LaVeist and Wallace, 2000; Gorman and Speer, 1997). Using nationally representative data for all public secondary schools in the United States, Sturm (2007) also finds that the percentage of minority students, especially Asian students, positively predicts the number of liquor stores within 400m buffer around the schools which they attend. From an ecological standpoint, higher levels of alcohol outlets and advertising within minority and poorer communities stand in stark contrast to lower rates of alcohol use among minorities. Individual-based estimates of alcohol use show equal or lower alcohol consumption by African Americans, Hispanics, and Asians compared to Non-Hispanic Whites. Data from the National Center for Health Statistics reveal that 66% of Non-Hispanic White adults report currently drinking compared to 47% of African Americans and 50% of Hispanics. Among adult drinkers, 11% of Non-Hispanic Whites report drinking more than one drink for women and two drinks for men, compared to 9% for African Americans or 7% for Hispanics (Schoenborn et al., 2004). While consumption is higher among Non-Hispanic Whites, rates of alcohol dependence and abuse appear roughly equal across racial categories (Harford et al., 2005). The mismatch between supply and demand in term of the geographical location of alcohol retails may cause minority and low-income residents to suffer disproportionately from alcohol-related problems such as violent crimes (Zhu, 2004; Speer et al., 1998; Gorman et al., 2001), motor vehicle crashes and assault violence (Scribner et al., 1994, 1995), arrest rates for public drunkenness, misdemeanor, and felony drunken-driving (Rabow and Watts 1982; Watts and Rabow, 1983), child maltreatment rates (Freisthler et al., 2005), and homicide rates (Scribner et al., 1999).

This study has several important limitations. Observational studies of neighborhood effects are subject to the self-selection bias - people choose where to live. Drinkers with certain unobserved or unobservable characteristics can choose to live nearby alcohol outlets thus making it appear that the presence of outlets has a larger effect than it really does without self-selection. Our study focuses on children under 18 years of age, who in practice have no influence over their residential location for the kind of reasons we are concerned. However, the self-selection bias can still be operated through their parents. Controlling for multiple cofactors including parent drinking behavior in the regression model can help mitigate but probably does not completely remove the self-selection bias. Drinking behavior of only one interviewed parent/guardian is available and the measures are limited in themselves. In a sensitivity analysis, we computed the same alcohol outlet statistics for the full sample of all households (with and without children). As reported in Table 3.3, the mean number of alcohol outlets is higher for all sociodemographic groups, suggesting that households with children do sort themselves into neighborhoods with fewer alcohol outlets around their home.

Our methods were designed to systematically detect locational patterns of alcohol outlets in relation to the resident sociodemographics. However, the underlying mechanisms to produce the observed site selections, in addition to the possible self-selection bias, are not known to us. There are certainly many reasons, varying from city zoning regulations on commercial land use to economic factors that affect decisions made by the alcohol retail industry. Nevertheless, the existing location pattern poses an important public health concern and the underlying processes deserve to be explored in future studies. Another limitation is that our sample is not big enough to detect interactions between sociodemographic groups and alcohol sales, especially because the determinants of adolescent drinking tend to offset each other. For instance, higher income families are more likely to have children who drive simply because they are more likely to own cars. Thus these children are more likely to be engaged in driving after drinking even though they are the least exposed to alcohol sales. Similarly, Asian adolescents are less likely to drink though they are the most exposed to alcohol sales.

Many long-term health behaviors are shaped during youth. Problems that require treatment often do not manifest themselves until much later in life, raising the importance of primary prevention for that age group. Our study suggests that ceteris paribus, proximity matters! Living in close proximity to alcohol outlets is a risk factor, particularly for youth from lower income and minority families for whom neighborhood outlet concentration is higher. Disparities in alcohol-related health risks can be worsened by alcohol sales' direct effects on problem drinking and indirect effects such as violent crime and drunk driving. Environmental interventions need to curb opportunities for youth to get alcohol from commercial sources, whether being through tightening licensure, enforcing minimum age drinking laws, or reducing community tolerance for underage alcohol use. The fact is that the highest prevalence of alcohol dependence in the U.S. population is among people ages 18 to 20 (Grant et al., 2004), who typically started drinking earlier in their teenage years (Grant and Dawson, 1997).

Parents need to be better educated about the risks their children face, as too often they underestimate how early their children drinking begins, how much alcohol children consume, and how much damage underage drinking can cause (U.S. Department of Health and Human Services, 2007). Regulations placing external pressure on parents may be an effective option. Recently, many cities in California, New Jersey, Wisconsin and elsewhere have passed laws that give police authority to respond to home parties and fine adults who permit underage drinking (John Ritter, 2007). Last but not least, interventions aimed at adolescents themselves need to account for dynamic interactions between individuals and the neighborhood environment.

Table 3.1: Descriptive Statistics for CHIS 2003

Variable	Mean	Std. Dev.
Households with children under 18 (n=14,595)		
White (non-Hispanic)[a]		
Lowest income quartile	0.108	(0.31)
2nd income quartile	0.225	(0.42)
3rd income quartile	0.307	(0.46)
Highest income quartile	0.360	(0.48)
Black (non-Hispanic)[a]		
Lowest income quartile	0.320	(0.47)
2nd income quartile	0.277	(0.45)
3rd income quartile	0.252	(0.43)
Highest income quartile	0.151	(0.36)
Hispanic[a]		
Lowest income quartile	0.504	(0.50)
2nd income quartile	0.330	(0.47)
3rd income quartile	0.119	(0.32)
Highest income quartile	0.047	(0.21)
Asian & Pacific Islander[a]		
Lowest income quartile	0.208	(0.41)
2nd income quartile	0.250	(0.43)
3rd income quartile	0.251	(0.43)
Highest income quartile	0.291	(0.45)
Other races[a]		
Lowest income quartile	0.329	(0.47)
2nd income quartile	0.316	(0.47)
3rd income quartile	0.224	(0.42)
Highest income quartile	0.132	(0.34)
Adolescent sample (n=3,660)		
Ever had acoholic drinks	0.351	(0.48)
At least 1 drink past 30 days	0.150	(0.36)
Any binge drinking past 30 days	0.056	(0.23)
Ever driving after drinking[b]	0.060	(0.24)
Current smoker	0.050	(0.22)
Marijuana use past 30 days[c]	0.050	(0.22)
Female	0.489	(0.50)
Age	14.362	(1.67)
Teens worked for pay past 12 months	0.405	(0.49)
Parents married or living with a partner	0.822	(0.38)
Parent's excess drinking	0.021	(0.13)
Parent's binge drinking past month	0.131	(0.34)

Note:

[a]: Race/ethnicity is of the interviewed adult.

[b]: Denominator is adolescents aged 16 or older who ever had more than a few sips of alcoholic drinks.

[c]: Denominator is adolescents with parent/guardian's permission (98.7%). All statistics are weighted.

Table 3.2: Mean Number of Alcohol Outlets around Residences by Race/Ethnicity and Income - Sample Includes Households with Children Ages 0-17[a]

			Radii 0.1 mile	Radii 0.3 mile	Radii 0.5 mile	Band 0.5-1.0 mile	Band 1.0-2.0 mile
		All Race/Ethnicity Groups	**0.30**	**2.75**	**7.27**	**19.20**	**61.55**
A	**All Income Groups**	*White (Ref. Grp)*	0.21	1.94	5.48	15.23	49.78
		Black	0.24 ***	2.42 ***	6.46 ***	17.50 ***	63.63 ***
		Hispanic	0.39 ***	3.28 ***	8.49 ***	21.79 ***	68.38 ***
		Asian/Pacific Islander	0.33 ***	3.74 ***	9.51 ***	24.04 ***	74.53 ***
		Other races	0.36 ***	2.59 ***	6.58 **	19.15 **	62.44 **
B	Lowest Income Quartile	*White (Ref. Grp)*	0.27	2.51	6.53	16.87	49.66
		Black	0.30 *	3.42 ***	8.71 ***	21.46 ***	78.42 ***
		Hispanic	0.47 ***	3.88 ***	9.85 ***	24.72 ***	76.79 ***
		Asian/Pacific Islander	0.53 ***	5.34 ***	12.55 ***	29.54 ***	96.67 ***
		Other races	0.44 **	3.64 ***	9.28 ***	21.20 **	68.27 **
C	**All Race Groups**	*1st Income Quartile (Ref. Grp)*	0.44	3.77	9.53	23.70	74.55
		2nd Income Quartile	0.34 ***	2.86 ***	7.36 ***	19.37 ***	59.81 ***
		3rd Income Quartile	0.20 ***	2.06 ***	5.86 ***	16.16 ***	52.52 ***
		Highest Income Quartile	0.16 ***	1.83 ***	5.37 ***	15.67 ***	54.54 ***
D	White	*1st Income Quartile (Ref. Grp)*	0.29	2.51	6.53	16.87	49.66
		2nd Income Quartile	0.28	2.30	6.06	15.34	48.09
		3rd Income Quartile	0.15 ***	1.61 ***	4.82 ***	14.14 **	45.47
		Highest Income Quartile	0.18 **	1.82 **	5.37 *	15.60	44.54 *
E	Black	*1st Income Quartile (Ref. Grp)*	0.30	3.42	8.71	21.46	78.42
		2nd Income Quartile	0.24 *	2.16 **	5.67 **	16.84	60.48 *
		3rd Income Quartile	0.24 *	2.09 ***	5.71 **	16.17 *	57.63 **
		Highest Income Quartile	0.10 **	1.32 ***	4.39 ***	12.58 **	48.16 ***
F	Hispanic	*1st Income Quartile (Ref. Grp)*	0.47	3.88	9.85	24.72	76.79
		2nd Income Quartile	0.35 ***	2.99 ***	7.63 ***	19.88 ***	62.48 ***
		3rd Income Quartile	0.23 ***	2.00 ***	6.22 ***	16.93 ***	54.90 ***
		Highest Income Quartile	0.15 ***	2.19 ***	5.58 ***	16.00 ***	53.93 ***
G	Asian/ Pacific Islander	*1st Income Quartile (Ref. Grp)*	0.53	5.34	12.55	29.54	96.67
		2nd Income Quartile	0.49	4.53	11.49	29.83	78.97 **
		3rd Income Quartile	0.21 **	3.69 **	9.22 **	22.10 **	70.54 ***
		Highest Income Quartile	0.14 ***	1.94 ***	5.86 ***	16.80 ***	58.31 ***
H	Other races	*1st Income Quartile (Ref. Grp)*	0.44	3.64	9.28	21.20	68.27
		2nd Income Quartile	0.34	2.32 *	5.58 *	19.69	65.23
		3rd Income Quartile	0.45	2.59	6.25	18.44	62.48
		Highest Income Quartile	0.06 **	0.64 ***	2.85 ***	13.98 **	41.21 *

Note:

[a]: Sample includes 14,595 households with children ages 0-17.

Band 0.5 mile-1.0 mile: the area between the 0.5 mile radius and 1.0 mile radius.

Band 1.0 mile-2.0 mile: the area between the 1.0 mile radius and 2.0 mile radius.

Reference group is in *Italic* in each panel. The asterisk (*) indicates significance at 5% level; ** significance at the 1% level; *** significance at 0.1% level. All statistics are weighted.

Table 3.3: Mean Number of Alcohol Outlets around Residences by Race/Ethnicity and Income - Sample Includes All Households[b]

			Radii 0.1 mile	Radii 0.3 mile	Radii 0.5 mile	Band 0.5-1.0	Band 1.0-2.0
		All Race/Ethnicity Groups	**0.38**	**3.44**	**8.95**	**22.86**	**71.87**
A	**All Income Groups**	*White (Ref. Grp)*	0.32	3.04	8.05	20.80	65.88
		Black	0.35 *	3.23 **	8.70 ***	22.33 ***	79.45 ***
		Hispanic	0.42 ***	3.53 ***	9.11 ***	23.37 ***	73.52 ***
		Asian/Pacific Islander	0.52 ***	4.93 ***	12.36 ***	29.96 ***	87.83 ***
		Other races	0.46 **	3.46 **	8.94 **	23.93 **	73.56 **
B	Lowest Income Quartile	*White (Ref. Grp)*	0.47	3.76	9.45	21.42	65.69
		Black	0.49	4.49 **	11.83 ***	28.01 ***	97.70 ***
		Hispanic	0.51 ***	4.20 ***	10.71 ***	26.85 ***	83.00 ***
		Asian/Pacific Islander	0.76 ***	7.06 ***	17.29 ***	38.70 ***	109.08 ***
		Other races	0.46	3.92 *	9.76	22.35	70.00 *
C	**All Race Groups**	*1st Income Quartile (Ref. Grp)*	0.52	4.42	11.18	26.58	81.68
		2nd Income Quartile	0.38 ***	3.37 ***	8.81 ***	22.20 ***	69.12 ***
		3rd Income Quartile	0.32 ***	2.98 ***	7.86 ***	21.01 ***	65.97 ***
		Highest Income Quartile	0.28 ***	2.83 ***	7.62 ***	21.10 ***	69.18 ***
D	White	*1st Income Quartile (Ref. Grp)*	0.47	3.76	9.45	21.42	65.69
		2nd Income Quartile	0.34 ***	3.21 **	8.52 **	20.99	65.42
		3rd Income Quartile	0.30 ***	2.84 ***	7.49 ***	19.99 *	62.50
		Highest Income Quartile	0.27 ***	2.74 ***	7.54 ***	21.06	61.11 *
E	Black	*1st Income Quartile (Ref. Grp)*	0.49	4.49	11.83	28.01	97.70
		2nd Income Quartile	0.28 ***	2.58 ***	7.52 ***	20.92 ***	73.24 ***
		3rd Income Quartile	0.33 ***	2.80 ***	7.30 ***	20.06 ***	72.91 ***
		Highest Income Quartile	0.20 ***	2.21 ***	6.00 ***	15.84 ***	60.09 ***
F	Hispanic	*1st Income Quartile (Ref. Grp)*	0.51	4.20	10.71	26.85	83.00
		2nd Income Quartile	0.34 ***	3.07 **	7.82 ***	19.88 ***	62.61 ***
		3rd Income Quartile	0.32 ***	2.53 ***	7.22 ***	19.67 ***	63.91 ***
		Highest Income Quartile	0.38 **	3.00 ***	7.34 ***	21.59 ***	73.54 ***
G	Asian/ Pacific Islander	*1st Income Quartile (Ref. Grp)*	0.76	7.06	17.29	38.70	109.08
		2nd Income Quartile	0.62 *	5.13 ***	13.21 ***	33.17 ***	97.61 ***
		3rd Income Quartile	0.39 ***	4.33 ***	10.79 ***	27.84 ***	79.03 ***
		Highest Income Quartile	0.32 ***	3.41 ***	8.71 ***	21.76 ***	69.58 ***
H	Other races	*1st Income Quartile (Ref. Grp)*	0.43	3.92	9.76	22.35	70.00
		2nd Income Quartile	0.51 *	4.21	9.67	23.57	81.11 **
		3rd Income Quartile	0.37 *	2.81 **	7.52 **	21.13	71.81
		Highest Income Quartile	0.26 ***	2.30 **	6.68 **	22.15	70.49

Note:
[b]: Sample includes 38,365 households living in urban.
Reference group is in *Italic* in each panel. The asterisk (*) indicates significance at 5% level; ** significance at the 1% level; *** significance at 0.1% level. All statistics are weighted.
Band 0.5 mile-1.0 mile: the area between the 0.5 mile radius and 1.0 mile radius.
Band 1.0 mile-2.0 mile: the area between the 1.0 mile radius and 2.0 mile radius.

Table 3.4: Race and Income as Predictors of Alcohol Outlets

All outlets within 0.5 mile	**Coef.**	**Std. Err.**	
White (Ref.)			
Black	0.19	(0.01)	***
Hispanic	0.26	(0.01)	***
Asian/PI	0.53	(0.01)	***
Other Races	0.08	(0.02)	***
Lowest income (Ref.)			
2nd income quartile	-0.23	(0.01)	***
3rd income quartile	-0.41	(0.01)	***
Highest income	-0.43	(0.01)	***
All outlets within band 0.5-1.0 mile			
White (Ref.)			
Black	0.23	(0.01)	***
Hispanic	0.25	(0.00)	***
Asian	0.45	(0.01)	***
Other Races	0.13	(0.01)	***
Lowest income (Ref.)			
2nd income quartile	-0.19	(0.01)	***
3rd income quartile	-0.30	(0.01)	***
Highest income	-0.27	(0.01)	***
All outlets within band 1.0-2.0 mile			
White (Ref.)			
Black	0.37	(0.00)	***
Hispanic	0.25	(0.00)	***
Asian	0.43	(0.00)	***
Other Races	0.13	(0.01)	***
Lowest income (Ref.)			
2nd income quartile	-0.18	(0.00)	***
3rd income quartile	-0.25	(0.00)	***
Highest income	-0.14	(0.00)	***

Note:
Reference group is in *Italic* in each panel.
*** indicates significance at 0.1% level.
All statistics are weighted.

Table 3.5: Effects of Alcohol Outlets on Adolescent Drinking

Explanatory Variable	(A) 1 drink past 30 days OR	Std. Err.		(B) 5 drinks past 30 days OR	Std. Err.		(C) Ever Driving after Driking OR	Std. Err.	
Off-sales 0.5 mile radius	1.002	(0.03)		1.026	(0.01)	*	1.059	(0.11)	
Off-sales 0.5-1.0 mile band	0.979	(0.02)		0.987	(0.01)		0.897	(0.08)	
Off-sales 1.0-2.0 mile band	0.996	(0.01)		1.000	(0.00)		1.052	(0.03)	
On-sales 0.5 mile radius	1.009	(0.01)		1.025	(0.01)	*	1.140	(0.05)	***
On-sales 0.5-1.0 mile band	0.999	(0.01)		0.991	(0.01)		0.989	(0.06)	
On-sales 1.0-2.0 mile band	1.004	(0.00)		1.000	(0.00)		0.968	(0.02)	
Female	0.953	(0.13)		0.648	(0.14)	*	0.571	(0.27)	
Age	1.603	(0.08)	***	1.789	(0.11)	***	2.048	(1.03)	
Hispanic	1.145	(0.22)		1.166	(0.43)		4.310	(2.42)	**
Asian/Pacific Islander	0.555	(0.17)	*	0.586	(0.26)		1.053	(1.39)	
Black	0.418	(0.16)	*	0.559	(0.39)		1.210	(1.25)	
Other races	0.821	(0.29)		1.068	(0.62)		2.066	(1.85)	
Work for pay past 12 months	1.136	(0.17)		1.176	(0.28)		1.002	(0.50)	
Current smoker	2.628	(0.77)	***	4.301	(1.52)	***	7.928	(4.03)	***
Marijuana use past 30 days	15.660	(4.40)	***	17.908	(5.71)	***	5.419	(2.21)	***
2nd income quartile	1.392	(0.30)		0.858	(0.30)		6.891	(4.90)	**
3rd income quartile	1.172	(0.29)		0.775	(0.29)		4.690	(3.29)	*
Highest income quartile	1.456	(0.40)		1.166	(0.44)		11.204	(9.51)	**
Parent's edu/highscl dimploma	1.081	(0.20)		1.083	(0.20)		1.083	(0.20)	
Parent's edu/some college	0.556	(0.24)		0.701	(0.13)		0.703	(0.13)	
Parent's edu/college or higher	0.379	(0.17)		0.639	(0.12)	*	0.732	(0.18)	
Parents' marital status	0.595	(3.00)	**	0.649	(0.19)		0.472	(0.25)	
Parent's excess drinking	0.284	(0.18)		0.142	(0.16)		0.301	(0.19)	
Parent's binge drinking	1.508	(0.33)		1.638	(0.48)		1.554	(0.69)	
Census tract population	1.000	(0.00)		1.000	(0.00)		1.000	(0.00)	
Tract median hshd income	0.937	(0.20)		1.025	(0.37)		0.833	(0.54)	
Tract % White population	0.605	(0.23)		0.985	(0.70)		3.323	(3.36)	
Tract % Black population	0.416	(0.37)		0.981	(1.59)		3.094	(2.06)	

Note:
The asterisk (*) indicates significance at 5% level; ** significance at the 1% level;
*** significance at 0.1% level. All statistics are weighted.

Table 3.6: Simulated Prevalence of Adolescent Drinking by Alcohol Availability

Mean Number of Alcohol Outlets within 0.5 mile from Residences	Heavy Drinking Episode	Ever Driving After Drinking
Asian Level (Ua = 9.51)	0.064 (0.060, 0.068)	0.079 (0.068, 0.090)
White Level (Uw = 5.48)	0.056 (0.052, 0.060)	0.060 (0.050, 0.069)
Lowest Income Level (Ul = 9.53)	0.064 (0.060, 0.068)	0.079 (0.068, 0.090)
Highest Income Level (Uh = 5.37)	0.056 (0.052, 0.060)	0.059 (0.049, 0.068)
Asian Lowest Income Level (Ual = 12.55)	0.067 (0.063, 0.070)	0.098 (0.085, 0.109)
White Highest Income Level (Uwh = 5.37)	0.056 (0.052, 0.060)	0.059 (0.049, 0.069)

Note:
Regression model with total number of alcohol outlets as key explanatory variables is used.
95% confidence intervals are reported in parentheses. All statistics are weighted.

Chapter 4: Spatial Location of Alcohol Outlets and Problem Drinking among Adults in California[3]

Abstract

Objective: To examine the relationship between alcohol environments and problem drinking including excessive alcohol consumption, heavy episodic drinking, driving after drinking, and riding with a drinking driver.

Method: We merge geo-coded individual-level data from the California Health Interview Survey and Los Angeles County Health Survey to alcohol license data from the California Department of Alcoholic Beverage Control, distinguishing off-sale retails from on-sale establishments, and among on-sales, eating places from bars, and taverns, as well as, minor-unrestricted establishments from minor-restricted establishments (youth under age 21 not allowed on business premises). The primary explanatory variable is alcohol outlets within various distances from an individual's residence or census tract. Multivariate logistic regression and simulation are run for men and women separately.

Results: On-sale establishments, particularly minor-restricted establishments, are significantly associated with excessive alcohol consumption and heavy episodic drinking, after controlling for individual and neighborhood sociodemographics. The effect is limited to outlets located within proximity, roughly one mile from residential homes. Off-sale retails is not found related to problem drinking. If the number of minor-restricted establishments increases from median to 90th percentile of their distribution, heavy episodic drinking would increase from 11.1% to 14.3% among women and from 19.6% to 22.0% among men.

Conclusion: Certain types of alcohol retailers in neighborhoods are associated with problem drinking. Moratorium of new licenses based on number of licenses per capita at county level is not effective because only a subgroup of licenses matters and alcohol is more available in terms of distance, travel time or search costs in densely populated cities.

Key words: problem drinking, alcohol availability, alcohol policy

[3] Truong KD, Strum R. Alcohol outlets and problem drinking among adults in California. J Stud Alcohol. In press.

INTRODUCTION

State and local governments often regulate alcohol outlets by placing limits on the number of available licenses, typically in relation to population. California imposes a moratorium on the issuance of retail licenses when the ratio exceeds one on-sale general license for each 2,000 persons and one off-sale general license for each 2,500 persons in the county in which the premises are situated. The list of moratorium counties includes every county with less than 300,000 residents, all counties with low population densities but none of the more densely populated counties with more than one million residents (Department of Alcoholic Beverage Control, 2005). As a consequence, in counties that are not restricted by the moratorium for additional licenses, alcohol is more available in terms of individual distance to alcohol outlets, travel time or search costs.

The rationale behind the moratorium regulation is the belief that a high density of alcohol outlets causes alcohol-related problems. Ecological studies found that alcohol outlets were associated with motor vehicle crashes, assault violence (Scribner et al., 1994, 1995), arrest rates for public drunkenness, misdemeanor and felony drunken-driving, cirrhosis mortality rates (Rabow and Watts 1982; Watts and Rabow, 1983), violent crimes (Speer et al., 1998; Gorman et al., 2001; Zhu et al., 2004), child maltreatment rates (Freisthler et al., 2005), and homicide rates (Scribner et al., 1999). However, making inferences about individual behaviors based on aggregate relationships in ecological studies can be misleading - a problem known as the ecological fallacy (Robinson, 1950). Ecological fallacy refers to an error in interpretation of statistical data, whereby inferences about certain individual behaviors are based solely on aggregate statistics collected for the group to which those individuals belong. We however agree in theory with the suggestion of the previous studies that alcohol outlets can have an independent effect on alcohol consumption and alcohol-related problems through different pathways that need further investigation.

More recent studies have complemented the literature by integrating individual-level data with environmental characteristics. This approach is developing and the findings so far are mixed, probably because most studies are specific to a small geographic area. Scribner et al. (2000) analyzed data from 24 census tracts in New Orleans, reporting that outlet density increased alcohol consumption through an effect at the neighborhood level rather than at the individual level. Using data from 4 cities in California, while Pollack et al. (2005) found no association between alcohol availability and heavy drinking, Treno et al. (2001) reported higher rates of self-reported injuries in areas with higher on- and off-sale outlet density, although those results were unadjusted for neighborhood sociodemographic composition. Gruenewald et al. (2002) found higher restaurant density associated with greater self-reported drinking frequency and driving after drinking, and higher bar density inversely related to driving after drinking. This study used a sample of 1,353 zip codes in California, thus had greater generalizability at the expense of a crude level of data resolution.

We examine the relationship between alcohol environments and problem drinking using individual level data from the California Health Interview Survey and the Los Angeles County Health Survey. Building on prior research, our study is designed to strengthen the current literature in four key dimensions. First, we further explore problem drinking by type of alcohol outlets as certain consumption behaviors are more likely to occur in their relevant context. Second, we investigate how spatial location of alcohol outlets may be related to problem drinking. Third, our data cover large geographical areas while the analysis focuses on small areas around respondents' home. And last, we know the exact location of approximately 37,000 individuals' residences. The geo-coded individual-level data facilitate us to build an analytic model that better reflects individual purchasing and consuming behaviors.

METHODS

Data

Alcohol Outlets

Data on alcohol outlets come from the California Alcoholic Beverage Control (ABC) database. This data underwent a database restructuring and inactive license purge in 1986 and in 1990 to create an archive suitable for tracking changes over time. There is detailed information on license types, business addresses, original date, and recent license renewal, ownership transfer, duplicate licenses, and multiple licenses for the same establishments. The main license types authorizing businesses to sell alcoholic beverages are type 20 – off-sale beer & wine; type 21 – off-sale general; type 40 – on-sale beer; type 41 – on-sale beer & wine eating place; type 42 – on-sale beer & wine public premises (no minors allowed on premises); type 47 – on-sale general eating place; and type 48 – on-sale general public premises (no minors allowed on premises). On-sale licenses and off-sale licenses together account for about 90 percent of all licenses. We exclude the remaining 10 percent, which primarily includes producers, manufacturers, wholesalers and special categories, such as excursion boats, trains, private clubs, and catering permits. There is also information on license status: active, inactive, not renewed, automatically revoked due to non-payment of renewal, indefinite suspension, revoked, cancel, and so on. We restrict the analysis to establishments with an active license during the health survey administration. In 2003, California had 30,650 active on-sale licenses and 21,836 active off-sale licenses, of which 7,966 on-sale and 6,550 off-sale were in Los Angeles County.

Los Angeles County Health Survey (LACHS)

LACHS is a population-based telephone survey that collects information on health status, health behaviors, and access to health services among adults and children in Los Angeles County. The adult survey 2002-03 includes 8,167 people aged 18 years or older. We drop 1,762 individuals for whom the survey lacks census tract information, which is required for this study. We also exclude the 245 people who are less than 21 years old (legal drinking age) because underage drinking is a different issue and this study focuses on the adult population. Los Angeles County has 2,054 census tracts with the median area of 0.45 square miles. Details on the LACHS are available at http://lapublichealth.org/ha/survey/hasurveyintro.htm.

To measure alcohol retailers in the neighborhoods, we performed three major tasks: geo-coding data, constructing geographic units (GUs), and measuring alcohol outlets in each GU, using ArcMap version 9.1. Geo-coding is a process of assigning geographic identifiers such as street address to map features and other data records. After converting street address of alcohol outlets to latitude and longitude, they are placed on a base map for merging with respondent data later. The finest geographical information available in LACHS is census tracts in which the respondents live. For each respondent, we created three additional GUs, called *buffers* extended from the census tract boundaries in 0.5 mile increments. We calculated the number of alcohol outlets located within each GU by spatially joining the GUs (containing census tracts and buffers, generally referred to as polygons in ArcMap) with the alcohol outlet data (containing geographical location of outlets). Buffers of a given census tract overlap with buffers of the adjacent census tracts, and therefore, the same outlets can be counted in multiple buffers. The use of buffers solves an inherent problem of pre-defined administrative areas such as census tracts or zip codes that they are mutually exclusive. Consequently, any outlet is located in only one census tract and accessed solely by residents living in that census tract. Multiple buffers help properly model the drinking behaviors that can occur in varying geographies.

California Health Interview Survey (CHIS)

CHIS is a computer assisted telephone interview survey, representative of the state's non-institutionalized population living in households. It uses a two-stage, geographically stratified random-digit-dial sample design. CHIS 2003 has 42,044 adults with 38,462 (91.5%) of them living in urban areas. We exclude 3,582 respondents living in rural area because characteristics of rural areas are very different and unlikely to be comparable. While the boundary of a typical census tract in an urban area is within walking distance, rural tracts in California can cover an area of over 1,000 square miles. We also drop 1,508 people less than 21 years of age from the analysis. Details on the CHIS are available at http://www.chis.ucla.edu/.

With information on the exact location of the respondents in CHIS, we use ArcMap to construct 4 circular areas with radii of 0.5 mile, 1 mile, 2 miles, and 3 miles centered at respondents' home. A 0.5 mile radius circle covers an area of 0.78 square miles, which is about the same size of the median census tract in California. The crucial difference, however, is that this area is centered around individual homes and always of the same size, which is almost never true for census tracts. The outer GUs are the *bands* between the 0.5 mile and 1.0 mile circles, between the 1.0 mile and 2.0 mile circles, and between the 2.0 mile and 3.0 mile circles. The process of measuring alcohol retailers in CHIS is similar to that of LACHS data.

Previous research and policy regulation have usually focused on outlet density as the number of establishments per square mile or 10,000 people, or per roadway miles for a fixed geographic size. We choose not to normalize the outlets in such ways, and instead consider an increasing range of geographies, from easy walking distance to distances that usually require motorized transportation. The raw count of outlets avoids some of the problems that occur with density per geographic area or population: A person may live close to outlets, yet the density may be almost zero if the area includes deserts or mountains. Similarly, in densely populated urban areas, the population definition may show low densities even when everybody lives within walking distance of an alcohol outlet.

Measure of Problem Drinking

There are four measures of self-reported individual problem drinking behaviors in the past month. The first one is the average monthly alcohol consumption. This measure is constructed by combining two original measures: frequency of drinking days and average number of drinks on drinking days. A drink was defined as a can or bottle of beer, 1 glass of wine, 1 can or bottle of wine cooler, 1 cocktail, or 1 shot of liquor by both surveys. We construct a dichotomous variable (Y1) by dividing the respondents into two groups: those consuming 60 drinks or less and those consuming more than 60 drinks in the past month. Moderate drinking is up to 60 drinks per month and may have some positive health effects (Coate, 1993; Doll et al., 1994; Fuchs et al., 1995, Camargo et al., 1997). Y1 is referred to as excess alcohol consumption in our analysis. The second measure is whether a respondent had at least one heavy drinking episode in the past month (Y2), defined by the LACHS as 5 drinks for men, and 4 drinks for women per occasion. In fact, there is no consensus on the definition of binge drinking (British Medical Association, 2006). The third measure is whether a respondent reported driving while perhaps having had too much to drink (Y3).

And the last measure is whether the respondent reported riding with a driver who has perhaps had too much to drink (Y4).

Only the first two measures, Y1 and Y2, are available in CHIS, which does not differentiate the number of drinks between men and women for a heavy drinking episode (5 drinks per occasion). These measures of problem drinking are complementary to one another. For instance, people may report a heavy drinking episode or reported an instance of driving after drinking but not necessarily consume an excessive amount of alcohol on a monthly basis. Complementary measures are important as the so called "prevention paradox" suggests that most alcohol-related harm in populations arises within the drinkers at low risk (Kreitman, 1986; Gmel *et al.*, 2001).

Statistical Methods

All four drinking measures are dichotomous and multivariate logistic models with heteroskedasticity robust standard error adjusted for clustering are employed. CHIS oversamples counties with small populations and includes multiple techniques to achieve statistically robust samples of several ethnic population groups. Similarly, LACHS also uses complex sampling design. To generalize the survey data to the overall population, both surveys developed appropriate weights that adjusted for differences in the probability of selection of respondents in each survey population attributable to the sampling design, and for differential contact and response rates among sub-populations during the survey process. To generalize our results to the general population, we use sampling weight options in Stata for both descriptive statistics and regression model. The multivariate logistic model is specified as follows.

$$\text{Logit}\,[Y_{i,g}] = \alpha + O_g\beta 1 + N_g\beta 2 + X_{i,g}\beta 3$$

where

- $Y_{i,g}$ represents the probability of person i in GU g engaged in some problem drinking.
- Logit [$Y_{i,g}$] is the log odds of problem drinking i.e. log[$Y_{i,g}$/(1 - $Y_{i,g}$)].
- α is the intercept.
- O_g represents a vector of the key explanatory variables that measure the number of alcohol outlets in GU g (i.e. census tract/circle, first buffer/band, second buffer/band, and third buffer/band). Counts of outlets in the outer bands/buffers do *not* include those located within the inner buffers/bands.
- N_g is a vector of neighborhood characteristics including census tract g's median household income, number of households, percent of Black population, and percent of White population (data extracted from US Census 2000, United States Census Bureau).
- $X_{i,g}$ includes individual i's employment status (employed full time or part-time vs. other); marital status (married or living with partner vs. other), education (no high school, high school diploma, some college, and college and higher); age groups; race (White, Black, Hispanic, Asian & Pacific Islander, and other); income groups (7 groups in LACHS or before-tax annual household income in CHIS), and smoking status (current smoker vs. not a current smoker).
- $\beta 1$, $\beta 2$, and $\beta 3$ represent vectors of the parameters to be estimated.

We hypothesize that the commercial availability of alcohol in neighborhoods affects individual drinking behavior and the effect diminishes quickly with distance. For each dependent variable (Y1-Y4), we estimate several models that differ by the key explanatory variables. The rationale for using multiple specifications is that drinking is often imbedded in social context, and we attempt to test if drinking setting matters. We start with a model in which the total number of alcohol outlets is the key explanatory variable (specification 1). This model investigates whether the overall availability of alcohol sources in neighborhoods affects drinking behavior. Its weakness is that lumping all alcohol sources and drinking location types into one measure can obscure plausible multiple drinking behaviors in relation to various drinking settings. We therefore split the total number of licenses into off-sale licenses (specification 2), and on-sale licenses (specification 3). The most likely location for alcohol consumption from off-sale purchase is home, whereas on-sales can include restaurants, bars, taverns, night clubs and so on. We therefore split the on-sales further. For LACHS, we estimate models that differentiate minor-unrestricted licenses (specification 4a) from minor-restricted licenses (specification 5a). For CHIS, we estimate separate models for restaurants and eating places (specification 4b) and bars and taverns (specification 5b). The difference between specifications 4a, 5a for LACHS and 4b, 5b for CHIS is license type 20, which makes up only 2.1% of the total retail licenses.

We translate the estimated odd ratios of the logistic regressions into a more easily understandable format by a counterfactual simulation. Assuming that the whole population had an increase in exposure to alcohol environments, from the median to the 90^{th} percentile of distribution of alcohol outlets around their home, we then estimate the change in the prevalence of problem drinking.

We do not adjust the significance levels for multiple comparisons like Bonferroni or Sidak adjustment (Abdi, 2007) because we expected a priori that outlets located further away are less associated with drinking outcomes and that a single category for all outlets can obscure and render statistically insignificant association. For example, we would not expect that the number of off-sale outlets is significantly associated with driving after drinking.

In principle, multi-level or hierarchical modeling is an appropriate analytic method when investigating individual-level outcomes in relation to the central explanatory variables that are characteristics of the environment. We actually conducted a statistical analysis with a multilevel model for LACHS.[4] We started with an *empty model*, where only an intercept was included and allowed to vary across Gus (random intercept model). The estimated unconditional intraclass correlation (ICC) from this model indicated the proportion of variation in drinking behavior *between* neighborhoods as opposed to the total variation (which is the sum of *between* neighborhood variation and *within* neighborhood variation). The estimated unconditional ICC was less than 5% for most of the drinking outcomes, indicating too little variation of drinking behaviors across the GUs. Multilevel modeling is meaningful only when there is enough variation of drinking behaviors, leaving some possible explanatory power for the environmental factors. That is more likely to happen when there is substantial clustering, for instance, when student test scores are analyzed and there are 20 or 30 students in each class. In the extreme case of only one observation per geographical unit, hierarchical models are observationally equivalent to single level models and cannot be identified. The analytic LACHS data have 6,160 respondents who are residentially distributed in 1,660 census tracts. Analytic CHIS has bigger sample size (37,000 respondents) but also more tracts (6,610). Even if there is large variation of drinking behaviors between neighborhoods in reality, and the analytic data size is large, evidence of this variation can still be neglected due to: a) a small average number of observations per GU, b) even a smaller number of observations of outcomes of interest, and c) unfavorable spatial distribution of health behaviors to detect variation. All of these constraints are observed in LACHS. We focused on small areas around individual home, and therefore the GUs are very small, each

[4] Technical specifications of the hierarchical model are presented in Appendix 1. Because the alcohol environment is developed for each individual respondent in CHIS, multilevel model is not applicable.

containing only a few number of respondents on average. It is harder to detect variation in dichotomous variables than in continuous variables. For instance, LACHS analytic data have only about 230 people who reported riding with a drinking driver. These people resided in 209 census tracts, resulting in only 1.08 respondents on average per census tract. How much this drinking behavior would vary between GUs also depends on the residential distribution of these people. In a hypothetical situation, if these people uniformly resided in the GUs, there would be no variation between neighborhoods. The regression results for binge drinking for women with the estimated unconditional ICC larger than 5% are presented in Table 8 to showcase our effort.

Sensitivity Analysis

In CHIS, there are 46.6% of women and 31.1% of men who reported no alcohol consumption in the past month (hereafter referred to as alcohol abstainers). LACHS has 49.8% women and 33.4% men as abstainers. The sociodemographics of these people are remarkably different from those of people who drink. In general, alcohol abstainers are older, more likely non-White, have lower education, lower employment rate, and lower income. There are potentially other unobserved differences between drinkers and abstainers that are not controlled for in the regressions. Distinguishing features of abstainers that are discussed in other studies include poorer health status (Shaper, 1990) and weaker social networks (Skog, 1996). We therefore conduct sensitivity analysis using the same model specifications for the data without alcohol abstainers.

The direction of causality can never be answered in observational studies without strong assumptions. It is possible that certain type of individuals with unobserved/unobservable characteristics choose to reside near alcohol outlets. And because we cannot control for those characteristics in the regression, the results would be biased. We therefore conduct a test to detect if self-selection bias exists in the analytic data. At the population level, heavy drinking, smoking, and sedentary lifestyle are significantly correlated. If drinkers, who are also more likely to smoke or be sedentary, choose to locate near alcohol outlets, then alcohol outlets should also be associated with the likelihood of being a smoker or having a sedentary lifestyle. In contrast, if there is no such self-selection bias, alcohol outlets would not be related to smoking behavior or sedentary lifestyle. With that thought experiment, we use the same right-hand side of the regression model for drinking behaviors to test whether alcohol availability predicts respondents' smoking status or physical activity (constructed by two measures: number of times walking for at least 10 minutes for fun in past 7 days and average time walked for fun or exercise). If the null hypothesis cannot be rejected, the self-selection bias would be a lesser concern.

The quality of alcohol license data can affect the results to a large extent. We use a different source of alcohol data to cross-check the quality of ABC data. InfoUSA collects information on approximately 11 million private and public U.S. companies. Individual businesses are located by address geocoding and can be retrieved by the North American Industry Classification System (NAICS) codes. The advantage of using infoUSA data is that geocoding has already performed and it is claimed that 88 percent of the businesses are coded at the address level and 99.8 percent are assigned to a census block group. There are, however, two disadvantages of infoUSA data. First it is created for business purposes (e.g.: locating competitors and marketing opportunities), and thus one needs to be careful with the quality of data. Second, there is a mismatch in the categorization of alcohol businesses between ABC and infoUSA data. ABC licenses are grouped by types, which are officially defined by the California Department of Alcoholic Beverage Control. InfoUSA data list the main business activity only. The two NAICS codes related to alcohol retailers are 4453 for beer, wine, and liquor stores and 7224 for alcoholic drinking places. Overall, infoUSA surely does not have comprehensive information on alcohol retailers compared to ABC data. We use infoUSA data to check if there are single retailers exist in infoUSA but not in ABC.

RESULTS

Descriptive Statistics

Table 4.1 presents mean, median and 90th percentiles of different types of alcohol outlets located in various GUs. Within 0.5 mile radius of individual homes in California, the median number of total alcohol licenses is 4. In the first band, the corresponding statistic is 13. In Los Angeles County, the median number of total alcohol licenses in census tracts is 7 and increases to 30 in the first buffer. Of all licenses in California, about 8% are bars and taverns (types 40, 42, and 48) and 6% are minor-restricted establishments (type 42 and 48). The mean is always bigger than the median indicating a high concentration of outlets in some areas.

Table 4.2 presents descriptive statistics of respondents' drinking behaviors and sociodemographics. There are no noticeable differences in the mean reported drinking patterns between the two datasets except for heavy episodic drinking among women. It is 6.6% in California against 10.7% in Los Angeles County. This discrepancy can be partly attributable to the different definition of a heavy drinking episode between the two surveys. It is only 4 drinks on an occasion for women in LACHS compared to 5 drinks on an occasion in CHIS. Previous studies have shown that factual distribution of alcohol consumption is strongly and positively skewed (Duffy, 1977; Skog, 1985; Skog, 1993). In CHIS, 0.6% of women and 5.4% of men reported consuming more than 60 drinks per month. Problem drinking appears to be more serious among men in the other indicators as well, unless women are more likely to underreport their alcohol consumption. Prevalence of reported heavy episodic drinking is as high as 23.5% among men compared to 6.6% among women in CHIS, or 22.1% compared to 10.7% in LACHS. There are about 1.2% of women and 3.7% of men who reported driving after having too much to drink, and 3.3% women and 4.3% men who reported riding with a driver, who perhaps had too much to drink in Los Angeles County. If the alcohol abstainers are excluded from the denominators, more than one third of men and about one seventh of women reported engaged in heavy episodic drinking. Similarly, among those who drink, the proportion of men and women who reported driving after having too much to drink are 5.6% and 2.6%, respectively. Measures of problem drinking are of *the past month*, portraying a serious alcohol problem in California.

In both surveys, abstainers are remarkably different from non-abstainers. They have much lower employment rates: 46.6% vs. 63.0% for women and 64.6% vs. 78.3% for men; lower education level: 31.2% vs. 9.7% of no high school diploma, and 22.6% vs. 39.8% of college education or higher among women; and 30.0% vs. 14.5% of no high school diploma and 20.0% vs. 34.9% of college education or higher among men; dominantly non-White: 38.9% vs. 64.1% of White women, 43.0% vs. 55.1% of White men; and much lower annual household income: $44,516 vs. $73,102 for women, and $52,312 vs. $74,738 for men. These statistics are estimated from CHIS and not shown in Table 4.2.

As presented in Table 4.10, characteristics of 1,762 respondents who lack census tract information and excluded from the analytic data are different from that of those included in the analysis using LACHS. Though the difference is not always statistically significant, generally those without census tract information drink less (less likely to drink at all, drink less often, less likely to binge-drink or drive after drinking), but are more likely to be with a drinking driver. They are more likely to be non-White, younger, less educated, and belong to lower income groups. It is not possible to detect whether there is some systematic manner in which the respondents without geographical identifier report their drinking behaviors and characteristics. Regardless of the underlying causes, the non-randomness of analytic data adversely affects the external validity of findings based on LACHS.

Regression Results

The main results come from 60 regressions of which 40 use LACHS (four outcomes, five specifications each, separately for men and women) and 20 use CHIS (two outcomes, five specifications each, separately for men and women). Tables 4.3 and 4.4 summarize all regression results by the estimated odds ratios (ORs) and their robust standard errors of the key explanatory variables – the number of alcohol outlets located in each GU. The five model specifications are listed horizontally and numbered from I – V for each of the 4 dependent variables, which are listed vertically and indexed from A to D. Due to space limitations, Tables 4.3 and 4.4 do not show estimated coefficients for the other explanatory variables.

There are four key findings from the regressions. First, off-sale outlets are not associated with any problem drinking indicators across GUs, gender, and datasets. Second, a subgroup of on-sale licenses are consistently and significantly associated with excess alcohol consumption, heavy episodic drinking, after controlling for individual and neighborhood sociodemographics. Third, there is some evidence of positive association between the *total* number of licenses and heavy episodic drinking but this finding does not provide a policy implication as there are possibly multiple relationships between various types of licenses and drinking behaviors. And last, the positive association between alcohol availability and problem drinking tends to hold for outlets located within short distances, generally less than

1 mile, from the respondent homes and diminishes for those located further out. The longer the distance to outlet locations, the weaker the connection with problem drinking as indicated by both statistical significance and magnitude of the estimated ORs.

Los Angeles County

On-sale minor-restricted licenses are found to be significantly and positively associated with excess alcohol consumption ($p < .05$). The marginal effect of outlets located in the census tracts is non-trivial with the estimated OR of 1.61 (95% CI: 1.02, 2.52) for women and of 1.26 (95% CI: 1.03, 1.54) for men. As the base rate of this drinking behavior is as low as 0.8% among women, and the marginal effect is translated into an increase to 1.28% (increase by 60.0%), if there is one more on-sale minor-restricted license in the respondents' census tracts. The base rate of excess alcohol consumption is 4.1% among men, and the estimated marginal effect increases the prevalence to 5.1% (increase by 24.4%).

On-sale minor-restricted licenses are also found to be significantly associated with heavy episodic drinking for women ($p < .05$) but not for men. The estimated OR is 1.18 (95% CI: 1.03, 1.34) for women and 1.09 (95% CI: 0.98, 1.21) for men. The base rate of heavy episodic drinking among women is 10.7%. The estimated marginal effect is equivalent to an increase in the prevalence among women to 12.4% (increase by 15.8%). In general, interpreting the estimated ORs is difficult and always dependent on the unit of analysis of the key explanatory variable. We translate these estimated OR into more meaningful aggregate statistics by a simulation whose results will be discussed shortly.

There is weaker evidence of positive effect of the on-sale minor restricted establishments on riding with a drinking driver ($p < .08$ for women and $p < .07$ for men). The estimated OR is 1.19 (95% CI: 0.98, 1.45) for women and 1.19 (95% CI: 0.99, 1.44) for men.

There is no clear relationship between problem drinking and other types of outlets in LACHS. Statistical significance of the coefficients of the on-sale licenses (model specification 3) is possibly attributable to the minor-restricted licenses as minor-unrestricted licenses is not found associated with any drinking indicators.

California

The observed relationship in LACHS is generally confirmed in CHIS at a higher level of statistical significance (p <0.01) perhaps due to greater statistical power. There is a slight modification of the model specifications for on-sale licenses in CHIS, where we distinguish number of restaurants and eating places (specification 4b) from number of bars and taverns (specification 5b). Among men, there is consistent evidence of a relationship between excess alcohol consumption and heavy episodic drinking with the *total* number of on-sale licenses, as well as each subgroup of the on-sale licenses. It is interesting to observe that women tend to engage in heavy episodic drinking at location further away from home (1.0 mile) than men do (0.5 mile). We wonder if it is a gender-sensitive issue that when women drink a lot, they do not want to go to places that are too close to their home to avoid encounter with familiar ones. The magnitude of the marginal effects in CHIS is however very small for both men and women. Similarly in LACHS, we do not observe any evidence of a relationship between off-sale licenses and problem drinking in CHIS.

Simulation Results

The simulation is conducted for LACHS. As shown in Panel I of Table 4.7, if the number of on-sale licenses increases from the median to 90th percentile, the heavy episodic drinking rate increases from 11.6% to 13.1% for women and from 20.0% to 21.0% for men. If only a subset of the on-sale licenses – the minor-restricted establishments, increases from the median to 90th percentile, the heavy episodic drinking rate increases from 11.1% to

14.3% among women and from 19.6% to 22.0% among men as shown in panel III of Table 4.7.

Similar results are found for riding with a drinking driver in this simulation. Prevalence increases from 3.3% to 3.5% among women and 4.3% to 4.9% among men if on-sale licenses increase from their median to 90th percentile. If minor-restricted licenses increase to 90th percentile, prevalence of riding with a drinking driver increases from 2.9% to 4.1% among women and 4.0% to 5.5% among men.

Note that in the simulation, we only changed the number of outlets located within the census tracts i.e. keeping those in the other buffers unchanged. This decision is based on the regression results that only the coefficients for outlets within census tracts are statistically significant. The absolute change of outlets from median to 90th percentile can be found in Table 4.1: from 3 to 12 for on-sale licenses, and from 0 to 2 for minor-restricted licenses.

Sensitivity Analysis

The regression models that use data without the alcohol abstainers strengthen the main findings. In addition to the consistency of the sign of all coefficients, the effects are stronger for most of the models and there is a statistically significant relationship for heavy episodic drinking among men in model specification 5a in LACHS. Results of the sensitivity analysis are reported in Tables 4.5 and 4.6.

As for the regressions to detect the self-selection bias, we find no significant association between alcohol outlets and smoking and physical activity, respectively, in all model specifications, datasets for both women and men. These outcomes suggest that the assumed self-selection bias does not seem to exist in the analytic data. Or in other words, we have stronger evidence of alcohol outlet effect on problem drinking because the possible unobserved process in which heavy drinkers sort themselves into areas with many alcohol outlets does not show up in the analytic data. We reported regression results of a sample test model in Table 4.9 in which minor-restricted outlets do not predict smoking status.

Our last sensitivity analysis is to use infoUSA data to check the quality of ABC data. California has 5,100 businesses under NAICS code 4453 (for beer, wine, and liquor stores) and 3,838 businesses under NAICS code 7224 (for alcoholic drinking places). Together, only 8,938 businesses are identified in infoUSA to be engaged in alcohol retails as compared to 52,485 *active* alcohol licenses from ABC data. One obvious reason for having this substantially large difference is that only the main business activity is listed in infoUSA. It is not possible to verify whether a restaurant (NAICS code 7221), a grocery store (NAICS code 44511), a convenience store (NAICS 44512) or a gasoline station (NAICS 44711) has an alcohol sales license.

We looked at a few groups of licenses in ABC and infoUSA that are close enough to make some comparison. For instance, license types 40, 42, and 48 (bars and taverns) in ABC are similar to NAICS code 7224 (alcoholic drinking places). While this group of ABC license types together has 4,369 licenses, there are only 3,838 businesses under NAICS code 7224. When the two data files are linked to each other, we find that there are identical businesses (the same business name and location) in both files but their alcohol license are no more active in the ABC data. In other words, infoUSA data include alcohol retailers that are no more in operation, or at least not legally permitted to sell alcoholic beverage according to information available from ABC data. ABC database, which contains sales licenses, is obviously more comprehensive and appropriate for the purpose of measuring the commercial sources of alcohol. We are not aware of other data sources that are more comprehensive than ABC data to detect its weaknesses.

DISCUSSION

Two different surveys of health behaviors have provided one consistent story: certain types of outlets in proximity matter when it comes to adult problem drinking. Our study supports the general belief that alcohol retailers in neighborhoods are associated with alcohol-related problems but the underlying relationships are more diverse. We validate the idea of categorizing alcohol outlets in the analytic model as drinking patterns are strongly tied to the choice of drinking venue (Gruenewald et al., 1995, 2002). While physical availability of alcohol is a necessary condition for problem drinking, social context appears to be an inducing factor. Bars, taverns, and night clubs, especially those that do not allow minors, are where social and cultural norms are more acceptable to or may even encourage excess drinking. Studies that use geo-coded individual-level data are for the most part either limited to small geographical coverage or based on crude data resolution. While focusing on micro GUs, our study covers California - the most populous state, and Los Angeles County with its population ranked 9th against US state populations (State and County QuickFacts, U.S. Census Bureau).

Kreitman's "prevention paradox" suggests that most alcohol-related harm in populations arises within the drinkers at low risk (1986). This view has had profound implications on alcohol policy and generated considerable controversy (Stockwell et al., 1996). Skog's study (1999) presented a pragmatic way of thinking about the prevention paradox. His empirical results suggest that the validity of the prevention paradox depends very much on the shape of the risk function, and hence that the role of the moderate drinkers may vary substantially across the spectrum of alcohol-related problems. He demonstrated that if the risk function is linear, the moderate drinkers will be responsible for the bulk of the problems. When the risk function is curved upwards, the heavy drinkers contribute a larger share of the problem. Measures of drinking behaviors in our study are basically average consumption and binge drinking that are studied by Gmel and his colleagues (2001). They found that moderate drinkers in terms of volume reported more problems than hazardous drinkers and binge drinkers reported more problems than non-binge drinkers. Binge drinkers in the moderate-volume and hazardous-volume drinking groups did not differ significantly as to either severity or number of problems. Their findings also indicate that, with respect to social harm, a preventive strategy aimed at the majority of the population, but on heavy-drinking occasions rather than on mean consumption, may be valuable.

There are important limitations of this study. First, it is a cross-sectional study, and regardless of the numerous regression models and sensitivity tests, causal effects need cautious interpretation. We do not have a good suggestion for a longitudinal study of this type either because license quota has reached its limit long ago in most counties and cities in California. Even if we had longitudinal data for drinking behavior, it would be unlikely to observe a lot of variation in alcohol data due to changes in location of businesses and respondents' residence. Randomized controlled trials of specific alcohol regulation in newly developed cities therefore are warranted as they can provide powerful evidence.

Another limitation is that drinking measures are self-reported. Though retrospective self-reports of alcohol consumption are ubiquitous in the alcohol research, they are subject to several influences of bias, depending on the time frames of these reports. Searles et al. (1995) reported that data collected on a daily basis is efficient but traditional methods of data collection such as quantity or frequency result in a significant underreporting bias for heavier drinkers. Other studies that assessed the validity and reliability of self-reported survey data on drinking behavior also found evidence to suggest that data are adversely affected by bias from underreporting (Embree and Whitehead, 1993; Stockwell et al., 2004). Gruenewald and Johnson (2006) however concluded that data on alcohol use from general population telephone surveys are generally reliable but reliability is a function of the stability of drinking patterns. Ostensibly unreliable self-reports may be reliable but may reflect unstable drinking patterns. As our measures of drinking behaviors are of the past 30 days, we believe that the estimated effects are reliable in the sense that they are based on conservative estimates of alcohol use self-reported by the respondents.

Overall, our findings point to the minor-restricted establishments as the group of licenses with the most consistent and sizeable effects on adult problem drinking, though they make up only about 6 percent of the total number of licenses. One policy implication of this insight is that limiting the total number of licenses is not as effective as tightening certain types of licenses. The evidence of a concentrated effect for outlets located in proximity of individual residences suggests that regulation needs to take into account the easier access to alcohol sales in densely populated cities. More adequate regulation requires an adjustment to the specific infrastructure conditions most likely at the city level. We find no link between off-sales and adult problem drinking. However, stricter regulation of off-sales may still be needed as other studies have shown that off-sale outlets are associated with underage drinking (Forster et al., 1995; Freisthler et al., 2003). New regulation is more feasible if it does not impose excess costs on businesses and consumers' safe alcohol consumption. License regulation itself is certainly not enough. Comprehensive measures such as tougher drunk driving laws, enforcement of underage drinking laws or change in social norms about drinking need to work together to solve alcohol-related problems.

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Table 4.1: Descriptive Statistics of Alcohol Outlets in California 2003

Outlet type	California				Los Angeles County			
	Geographical unit	Mean	Median	90th percentile	Geographical unit	Mean	Median	90th percentile
Total alcohol sales licenses	0.5 mi radius	8.7	4	20	Census tract	9	7	18
	1.0 mi band	22.4	13	46	0.5 mile buffer	37	30	74
	2.0 mi band	70.7	45	145	1.0 mil buffer	56	47	109
	3.0 mi band	92.3	60	196	1.5 mile buffer	72	64	135
Off-sales	0.5 mi radius	3.3	2	8	Census tract	4	3	7
	1.0 mi band	8.6	6	18	0.5 mile buffer	16	15	30
	2.0 mi band	27.5	19	58	1.0 mil buffer	25	23	46
	3.0 mi band	36.5	25	80	1.5 mile buffer	32	30	59
On-sales	0.5 mi radius	5.4	1	13	Census tract	5	3	12
	1.0 mi band	13.8	6	30	0.5 mile buffer	21	14	49
	2.0 mi band	43.2	24	92	1.0 mil buffer	31	22	70
	3.0 mi band	55.8	33	121	1.5 mile buffer	40	30	87
Eating places/Minor-unrestricted establishments[a]	0.5 mi radius	4.7	1	11	Census tract	5	3	11
	1.0 mi band	12.0	5	26	0.5 mile buffer	18	12	43
	2.0 mi band	37.5	20	81	1.0 mil buffer	32	22	69
	3.0 mi band	48.4	28	107	1.5 mile buffer	54	39	117
Bars and taverns/Minor-restricted establishments[b]	0.5 mi radius	0.8	0	2	Census tract	1	0	2
	1.0 mi band	2.1	1	5	0.5 mile buffer	3	2	6
	2.0 mi band	6.6	3	14	1.0 mil buffer	5	3	11
	3.0 mi band	8.5	4	19	1.5 mile buffer	8	6	16

Source: California Alcoholic Beverage Control Database

Note: California's statistics are based on 36,953 respondent residences in analytic CHIS.

Los Angeles County's statistics are based on 1,660 census tracts of analytic LACHS.

[a]: Eating places are applied to CHIS and minor-unrestricted establishments are applied to LACHS.

[b]: Bars and taverns are applied to CHIS and minor-restricted establishments are applied to LACHS.

Table 4.2: Descriptive Statistics of Respondents in CHIS 2003 and LACHS 2002-03

Variable	CHIS 2003				LACHS 2002-03			
	Female (n=21,766)		Male (n=15,187)		Female (n=3,435)		Male (n=2,725)	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Health-related behaviors								
Frequency of drinking days	3.32	(6.33)	6.05	(8.37)	2.84	(5.88)	5.17	(7.90)
Number of drinks per day	0.86	(1.21)	1.83	(2.34)	0.86	(1.41)	1.82	(2.61)
Excess alcohol consumption	0.006	(0.08)	0.054	(0.23)	0.008	(0.09)	0.041	(0.20)
Heavy episodic drinking	0.066	(0.25)	0.235	(0.42)	0.107	(0.31)	0.221	(0.42)
Driving after drinking	n/a	n/a	n/a	n/a	0.012	(0.11)	0.037	(0.19)
Riding with a drinking driver	n/a	n/a	n/a	n/a	0.033	(0.18)	0.043	(0.20)
Current Smoker	0.128	(0.33)	0.204	(0.40)	0.124	(0.33)	0.232	(0.42)
Walking for fun	0.581	(0.49)	0.542	(0.50)	n/a	n/a	n/a	n/a
Sociodemographics								
Employed	0.55	(0.50)	0.74	(0.44)	0.55	(0.50)	0.74	(0.44)
Married or w/ partner	0.62	(0.49)	0.68	(0.47)	0.59	(0.49)	0.63	(0.48)
No highschool diploma	0.21	(0.40)	0.20	(0.40)	0.23	(0.42)	0.21	(0.41)
High school diploma	0.22	(0.41)	0.21	(0.41)	0.22	(0.41)	0.21	(0.41)
Some college	0.27	(0.44)	0.23	(0.42)	0.28	(0.45)	0.27	(0.44)
College and higher	0.31	(0.46)	0.35	(0.48)	0.27	(0.45)	0.31	(0.46)
Age 21-30	0.20	(0.40)	0.21	(0.41)	0.24	(0.43)	0.25	(0.43)
Age 31-40	0.22	(0.42)	0.24	(0.43)	0.23	(0.42)	0.25	(0.43)
Age 41-50	0.21	(0.41)	0.22	(0.41)	0.20	(0.40)	0.20	(0.40)
Age 51-60	0.15	(0.36)	0.15	(0.36)	0.14	(0.34)	0.13	(0.34)
Age 61-70	0.10	(0.30)	0.09	(0.29)	0.08	(0.28)	0.09	(0.28)
Age over 70	0.12	(0.32)	0.09	(0.29)	0.11	(0.31)	0.08	(0.28)
White	0.51	(0.50)	0.51	(0.50)	0.51	(0.50)	0.51	(0.50)
Black	0.07	(0.25)	0.06	(0.24)	0.11	(0.31)	0.09	(0.29)
Hispanic	0.25	(0.43)	0.27	(0.44)	0.27	(0.44)	0.28	(0.45)
Asian & pacific islander	0.13	(0.34)	0.12	(0.33)	0.13	(0.34)	0.13	(0.34)
Other	0.04	(0.19)	0.04	(0.19)	0.02	(0.12)	0.01	(0.11)
Hshd income ($)	58,556	(67,042)	67419.43	(71,012)	n/a	n/a	n/a	n/a
Hshd income <$10K	n/a	n/a	n/a	n/a	0.12	(0.32)	0.08	(0.27)
Hshd income: $10K-20K	n/a	n/a	n/a	n/a	0.18	(0.38)	0.17	(0.38)
Hshd income: $20K-30K	n/a	n/a	n/a	n/a	0.13	(0.34)	0.14	(0.34)
Hshd income: $30K-40K	n/a	n/a	n/a	n/a	0.09	(0.29)	0.10	(0.30)
Hshd income: $40K-50K	n/a	n/a	n/a	n/a	0.08	(0.27)	0.10	(0.30)
Hshd income: $50K-75K	n/a	n/a	n/a	n/a	0.11	(0.31)	0.13	(0.34)
Hshd income > 75K	n/a	n/a	n/a	n/a	0.14	(0.35)	0.19	(0.40)

Source: California Health Interview Survey 2003 and Los Angeles County Health Survey 2002-03

Note: Statistics are weighted.

Table 4.3: Estimated Effects of Alcohol Outlets on Problem Drinking in LACHS

	Measures of Alcohol Availability	Geographical unit	A Excess Alcohol Consumption (Y1)		B Heavy Episodic Drinking (Y2)		C Drinking and Driving (Y3)		D With Drinking Driver (Y4)	
			OR	95% C.I.	OR	95% C.I.	OR	95% C.I.	OR	95% C.I.
WOMEN/LACHS										
I	Total alcohol sales licenses (Model 1)	Cencus tract	1.032	(0.99, 1.07)	1.015	(1.00, 1.03) *	0.997	(0.97, 1.03)	0.981	(0.96, 1.01)
		0.5 mi buffer	1.009	(0.99, 1.03)	0.997	(0.99, 1.00)	1.012	(0.99, 1.03)	1.004	(0.99, 1.02)
		1.0 mi buffer	0.992	(0.98, 1.01)	1.000	(0.99, 1.00)	0.996	(0.99, 1.00)	1.003	(1.00, 1.01)
		1.5 mi buffer	0.995	(0.99, 1.00)	1.003	(1.00, 1.01)	0.999	(0.99, 1.01)	1.000	(0.99, 1.01)
II	Off-sales (Model 2)	Census tract	1.074	(0.90, 1.29)	1.033	(0.99, 1.08)	0.953	(0.85, 1.07)	1.013	(0.93, 1.11)
		0.5 mi buffer	1.027	(0.94, 1.12)	0.989	(0.97, 1.01)	1.033	(0.98, 1.09)	1.014	(0.97, 1.06)
		1.0 mi buffer	1.007	(0.94, 1.08)	1.004	(0.99, 1.02)	1.021	(0.99, 1.06)	0.991	(0.97, 1.01)
		1.5 mi buffer	0.970	(0.94, 1.00)	1.005	(0.99, 1.02)	0.979	(0.94, 1.02)	1.013	(1.00, 1.03)
III	On-sales (Model 3)	Census tract	1.040	(0.99, 1.09)	1.018	(1.00, 1.03) *	1.002	(0.96, 1.04)	0.965	(0.93, 1.00)
		0.5 mi buffer	1.010	(0.99, 1.03)	0.998	(0.99, 1.01)	1.014	(0.99, 1.04)	1.006	(0.99, 1.02)
		1.0 mi buffer	0.985	(0.97, 1.00)	1.000	(0.99, 1.01)	0.989	(0.98, 1.00)	1.007	(1.00, 1.02)
		1.5 mi buffer	0.997	(0.98, 1.01)	1.004	(0.10, 1.01)	1.002	(0.99, 1.02)	0.998	(0.99, 1.01)
IV	On-sales minors unrestricted (Model 4a)	Census tract	1.053	(0.99, 1.12)	1.017	(0.99, 1.04)	1.013	(0.97, 1.06)	0.967	(0.93, 1.00)
		0.5 mi buffer	1.012	(0.98, 1.04)	0.993	(0.98, 1.00)	1.012	(0.97, 1.05)	1.005	(0.99, 1.02)
		1.0 mi buffer	0.986	(0.97, 1.01)	0.999	(0.99, 1.01)	0.987	(0.97, 1.00)	1.004	(0.99, 1.01)
		1.5 mi buffer	0.997	(0.98, 1.01)	1.005	(0.10, 1.01)	1.003	(0.99, 1.02)	1.000	(0.99, 1.01)
V	On-sales minors restricted (Model 5a)	Census tract	1.605	(1.02, 2.52) *	1.177	(1.03, 1.34) *	1.064	(0.65, 1.74)	1.193	(0.98, 1.45)
		0.5 mi buffer	1.296	(1.01, 1.67) *	0.993	(0.93, 1.07)	1.075	(0.88, 1.31)	0.962	(0.85, 1.09)
		1.0 mi buffer	0.885	(0.77, 1.02)	1.011	(0.97, 1.05)	1.014	(0.91, 1.13)	0.996	(0.93, 1.06)
		1.5 mi buffer	0.921	(0.78, 1.09)	1.010	(0.97, 1.05)	0.987	(0.89, 1.09)	1.039	(0.99, 1.09)
MEN/LACHS										
I	Total alcohol sales licenses (Model 1)	Census tract	1.009	(0.99, 1.03)	1.003	(0.99, 1.01)	1.003	(0.99, 1.02)	1.015	(1.00, 1.03)
		0.5 mi buffer	1.005	(0.99, 1.02)	1.003	(1.00, 1.01)	1.005	(1.00, 1.01)	0.999	(0.99, 1.01)
		1.0 mi buffer	0.998	(0.99, 1.01)	0.999	(0.99, 1.00)	1.004	(1.00, 1.01)	1.002	(0.99, 1.01)
		1.5 mi buffer	0.999	(0.99, 1.01)	1.001	(1.00, 1.00)	0.996	(0.99, 1.00)	1.001	(0.99, 1.01)
II	Off-sales (Model 2)	Census tract	1.062	(0.99, 1.14)	0.975	(0.94, 1.02)	0.983	(0.91, 1.06)	1.020	(0.95, 1.10)
		0.5 mi buffer	1.016	(0.98, 1.05)	1.012	(0.99, 1.03)	1.034	(1.00, 1.07)	1.003	(0.97, 1.04)
		1.0 mi buffer	0.984	(0.96, 1.01)	1.000	(0.99, 1.01)	0.992	(0.96, 1.02)	0.995	(0.97, 1.02)
		1.5 mi buffer	1.005	(0.99, 1.02)	0.998	(0.99, 1.01)	1.003	(0.98, 1.03)	1.010	(0.99, 1.03)
III	On-sales (Model 3)	Census tract	1.007	(0.98, 1.03)	1.007	(0.99, 1.02)	1.006	(0.99, 1.03)	1.019	(1.00, 1.04)
		0.5 mi buffer	1.005	(0.99, 1.02)	1.002	(0.99, 1.01)	1.002	(0.99, 1.01)	0.997	(0.99, 1.01)
		1.0 mi buffer	1.001	(0.99, 1.02)	0.999	(0.99, 1.01)	1.007	(1.00, 1.02)	1.004	(0.99, 1.01)
		1.5 mi buffer	0.998	(0.99, 1.01)	1.002	(1.00, 1.01)	0.994	(0.99, 1.00)	1.000	(0.99, 1.01)
IV	On-sales minors unrestricted (Model 4a)	Census tract	1.002	(0.97, 1.03)	1.007	(0.99, 1.02)	0.998	(0.97, 1.02)	1.013	(0.99, 1.04)
		0.5 mi buffer	1.006	(0.99, 1.02)	1.000	(0.99, 1.01)	1.009	(0.99, 1.02)	0.996	(0.98, 1.01)
		1.0 mi buffer	1.003	(0.99, 1.02)	1.000	(0.99, 1.01)	1.008	(1.00, 1.02)	1.006	(0.99, 1.02)
		1.5 mi buffer	0.998	(0.99, 1.01)	1.002	(1.00, 1.01)	0.993	(0.98, 1.00)	1.000	(0.99, 1.01)
V	On-sales minors restricted (Model 5a)	Census tract	1.259	(1.03, 1.54) *	1.090	(0.98, 1.21)	0.994	(0.78, 1.26)	1.194	(0.99, 1.44)
		0.5 mi buffer	1.108	(0.97, 1.27)	1.002	(0.95, 1.06)	1.026	(0.91, 1.16)	1.024	(0.92, 1.13)
		1.0 mi buffer	0.952	(0.88, 1.03)	0.985	(0.95, 1.02)	0.989	(0.92, 1.06)	0.988	(0.92, 1.06)
		1.5 mi buffer	0.957	(0.90, 1.02)	1.009	(0.98, 1.04)	0.986	(0.92, 1.05)	0.997	(0.95, 1.05)

Note: The asterisk (*) indicates significance at the 5% level (two-tailed test); ** significance at the 1% level (two-tailed test). Regressions are weighted.

Table 4.4: Estimated Effects of Alcohol Outlets on Problem Drinking in CHIS

	Measures of Alcohol Availability	Geographical unit	A Excess Alcohol Consumption (Y1) OR	95% C.I.		B Heavy Episodic Drinking (Y2) OR	95% C.I.	
	WOMEN/CHIS							
I	Total alcohol sales licenses (Model 1)	0.5 mi band	1.001	(0.99, 1.01)		0.998	(0.99, 1.00)	
		1.0 mi band	1.002	(0.99, 1.01)		1.004	(1.00, 1.01)	**
		2.0 mi band	1.000	(1.00, 1.00)		1.000	(1.00, 1.00)	
		3.0 mi band	1.001	(1.00, 1.00)		1.000	(1.00, 1.00)	
II	Off-sales (Model 2)	0.5 mi band	1.005	(0.99, 1.01)		0.999	(0.99, 1.00)	
		1.0 mi band	1.012	(0.99, 1.01)		1.010	(1.00, 1.01)	
		2.0 mi band	1.001	(1.00, 1.00)		1.002	(1.00, 1.00)	
		3.0 mi band	1.003	(1.00, 1.00)		0.999	(1.00, 1.00)	
III	On-sales (Model 3)	0.5 mi band	1.001	(0.99, 1.01)		0.998	(0.99, 1.00)	
		1.0 mi band	1.002	(0.99, 1.01)		1.005	(1.00, 1.01)	**
		2.0 mi band	1.001	(1.00, 1.00)		0.999	(1.00, 1.00)	
		3.0 mi band	1.000	(1.00, 1.00)		1.001	(1.00, 1.00)	
IV	On-sales - Restaurants & Eating Places (Model 4b)	0.5 mi band	1.003	(0.98, 1.03)		0.999	(0.98, 1.00)	
		1.0 mi band	1.003	(0.99, 1.02)		1.006	(1.00, 1.01)	**
		2.0 mi band	1.000	(1.00, 1.01)		0.999	(1.00, 1.00)	
		3.0 mi band	1.001	(1.00, 1.00)		1.001	(1.00, 1.00)	
V	On-sales - Bars & Taverns (Model 5b)	0.5 mi band	0.995	(0.94, 1.05)		0.987	(0.96, 1.04)	
		1.0 mi band	1.013	(0.97, 1.06)		1.024	(1.01, 1.04)	**
		2.0 mi band	1.012	(0.99, 1.03)		1.001	(0.99, 1.01)	
		3.0 mi band	0.999	(0.98, 1.02)		1.000	(0.98, 1.00)	
	MEN/CHIS							
I	Total alcohol sales licenses (Model 1)	0.5 mi band	0.994	(0.99, 1.00)		1.007	(1.00, 1.01)	**
		1.0 mi band	1.007	(1.00, 1.01)	**	0.998	(1.00, 1.00)	
		2.0 mi band	0.999	(1.00, 1.00)		1.000	(1.00, 1.00)	
		3.0 mi band	0.999	(1.00, 1.00)		1.000	(1.00, 1.00)	
II	Off-sales (Model 2)	0.5 mi band	0.980	(0.98, 1.02)		1.009	(1.00, 1.02)	
		1.0 mi band	1.000	(1.00, 1.02)		1.000	(0.99, 1.01)	
		2.0 mi band	0.996	(1.00, 1.01)		1.002	(1.00, 1.01)	
		3.0 mi band	0.997	(1.00, 1.00)		0.999	(1.00, 1.00)	
III	On-sales (Model 3)	0.5 mi band	0.995	(0.99, 1.00)		1.008	(1.00, 1.01)	**
		1.0 mi band	1.006	(1.00, 1.01)	**	0.998	(1.00, 1.00)	
		2.0 mi band	0.999	(1.00, 1.00)		1.000	(1.00, 1.00)	
		3.0 mi band	0.999	(1.00, 1.00)		1.000	(1.00, 1.00)	
IV	On-sales - Restaurants & Eating Places (Model 4b)	0.5 mi band	0.992	(0.99, 1.01)		1.011	(1.00, 1.02)	**
		1.0 mi band	1.009	(1.00, 1.01)	**	0.998	(0.99, 1.00)	
		2.0 mi band	0.999	(1.00, 1.00)		1.000	(1.00, 1.00)	
		3.0 mi band	0.999	(1.00, 1.00)		1.000	(1.00, 1.00)	
V	On-sales - Bars & Taverns (Model 5b)	0.5 mi band	1.001	(0.96, 1.02)		1.032	(1.01, 1.06)	*
		1.0 mi band	1.013	(1.01, 1.04)		0.989	(0.97, 1.01)	
		2.0 mi band	1.001	(0.99, 1.01)		1.005	(1.00, 1.01)	
		3.0 mi band	0.994	(0.99, 1.01)		1.000	(0.99, 1.00)	

Note: The asterisk (*) indicates significance at the 5% level (two-tailed test);
** significance at the 1% level (two-tailed test). Regressions are weighted.

Table 4.5: Sensitivity Analysis - Estimated Effects of Alcohol Outlets on Problem Drinking in LACHS - Analytic Data Excludes Alcohol Abstainers

	Measures of Alcohol	Geographical unit	(A)		(B)		(C)		(D)	With
			OR	**Std. Err.**	**OR**	**Std. Err.**	**OR**	**Std. Err.**	**OR**	**Std. Err.**
		WOMEN/LACHS								
I	Total alcohol sales licenses (Model specification 1)	Cencus tract	1.031	(0.019)	1.017	(0.007) *	0.992	(0.017)	0.980	(0.013)
		0.5 mi buffer	1.012	(0.010)	0.998	(0.004)	1.013	(0.009)	1.004	(0.006)
		1.0 mi buffer	0.991	(0.008)	1.000	(0.003)	0.996	(0.005)	1.003	(0.004)
		1.5 mi buffer	0.995	(0.004)	1.003	(0.002)	0.999	(0.006)	1.000	(0.003)
II	Off-sales (Model specification 2)	Census tract	1.083	(0.101)	1.038	(0.027)	0.943	(0.056)	1.013	(0.046)
		0.5 mi buffer	1.036	(0.042)	0.989	(0.011)	1.036	(0.033)	1.014	(0.022)
		1.0 mi buffer	1.012	(0.037)	1.004	(0.009)	1.022	(0.019)	0.991	(0.012)
		1.5 mi buffer	0.961	(0.084)	1.003	(0.006)	0.976	(0.022)	1.013	(0.009)
III	On-sales (Model specification 3)	Census tract	1.037	(0.023)	1.020	(0.009) *	0.998	(0.023)	0.965	(0.020)
		0.5 mi buffer	1.015	(0.010)	0.998	(0.005)	1.015	(0.011)	1.006	(0.007)
		1.0 mi buffer	0.982	(0.009)	1.000	(0.003)	0.990	(0.006)	1.007	(0.005)
		1.5 mi buffer	0.997	(0.006)	1.004	(0.003)	1.003	(0.007)	0.998	(0.005)
IV	On-sales minors unrestricted (Model specification 4a)	Census tract	1.053	(0.030)	1.019	(0.010)	1.009	(0.026)	0.967	(0.018)
		0.5 mi buffer	1.017	(0.014)	0.994	(0.006)	1.012	(0.017)	1.005	(0.008)
		1.0 mi buffer	0.983	(0.010)	1.000	(0.004)	0.988	(0.007)	1.004	(0.005)
		1.5 mi buffer	0.997	(0.006)	1.004	(0.003)	1.004	(0.007)	1.000	(0.004)
V	On-sales minors restricted (Model specification 5a)	Census tract	1.617	(0.370) *	1.189	(0.086) *	1.015	(0.276)	1.192	(0.120)
		0.5 mi buffer	1.304	(0.162) *	0.985	(0.039)	1.076	(0.105)	0.962	(0.061)
		1.0 mi buffer	0.864	(0.093)	1.013	(0.023)	1.018	(0.054)	0.997	(0.033)
		1.5 mi buffer	0.935	(0.077)	1.009	(0.020)	0.983	(0.051)	1.039	(0.023)
		MEN/LACHS								
I	Total alcohol sales licenses (Model specification 1)	Census tract	1.010	(0.009)	1.004	(0.006)	1.003	(0.009)	1.015	(0.008)
		0.5 mi buffer	1.006	(0.005)	1.004	(0.003)	1.005	(0.005)	0.999	(0.005)
		1.0 mi buffer	0.998	(0.006)	0.999	(0.003)	1.004	(0.004)	1.002	(0.004)
		1.5 mi buffer	0.999	(0.004)	1.001	(0.002)	0.996	(0.003)	1.001	(0.003)
II	Off-sales (Model specification 2)	Census tract	1.058	(0.039)	0.970	(0.022)	0.987	(0.039)	1.021	(0.039)
		0.5 mi buffer	1.018	(0.017)	1.016	(0.011)	1.033	(0.018)	1.003	(0.018)
		1.0 mi buffer	0.982	(0.014)	1.001	(0.008)	0.995	(0.016)	0.995	(0.013)
		1.5 mi buffer	1.005	(0.010)	0.997	(0.005)	1.002	(0.013)	1.010	(0.009)
III	On-sales (Model specification 3)	Census tract	1.008	(0.011)	1.009	(0.007)	1.005	(0.010)	1.019	(0.010)
		0.5 mi buffer	1.006	(0.006)	1.003	(0.004)	1.002	(0.006)	0.997	(0.006)
		1.0 mi buffer	1.001	(0.007)	0.998	(0.004)	1.007	(0.005)	1.004	(0.005)
		1.5 mi buffer	0.998	(0.005)	1.003	(0.002)	0.994	(0.004)	1.000	(0.004)
IV	On-sales minors unrestricted (Model specification 4a)	Census tract	1.003	(0.015)	1.010	(0.009)	0.998	(0.012)	1.013	(0.012)
		0.5 mi buffer	1.007	(0.008)	1.000	(0.005)	1.009	(0.008)	0.996	(0.008)
		1.0 mi buffer	1.003	(0.008)	0.998	(0.004)	1.008	(0.005)	1.006	(0.006)
		1.5 mi buffer	0.998	(0.005)	1.003	(0.003)	0.993	(0.005)	1.000	(0.005)
V	On-sales minors restricted (Model specification 5a)	Census tract	1.334	(0.154) *	1.139	(0.075) *	1.016	(0.127)	1.194	(0.114)
		0.5 mi buffer	1.125	(0.077)	0.999	(0.032)	1.026	(0.063)	1.024	(0.054)
		1.0 mi buffer	0.954	(0.042)	0.986	(0.022)	0.993	(0.037)	0.988	(0.037)
		1.5 mi buffer	0.952	(0.033)	1.012	(0.018)	0.983	(0.033)	0.997	(0.026)

Note: The asterisk (*) indicates significant at the 5% level (two-tailed test); ** significant at the 1% level (two-tailed test).
Regressions are weighted.

Table 4.6: Sensitivity Analysis - Estimated Effects of Alcohol Outlets on Problem Drinking in CHIS - Analytic Data Excludes Alcohol Abstainers

	Measures of Alcohol	Geographical unit	(A) OR	(A) Std. Err.		(B) OR	(B) Std. Err.	
			WOMEN/CHIS					
I	Total alcohol sales licenses (Model specification 1)	0.5 mi band	1.001	(0.007)		0.998	(0.003)	
		1.0 mi band	1.002	(0.005)		1.004	(0.002)	**
		2.0 mi band	1.000	(0.002)		0.999	(0.001)	
		3.0 mi band	1.001	(0.001)		1.000	(0.000)	
II	Off-sales (Model specification 2)	0.5 mi band	1.003	(0.014)		1.001	(0.010)	
		1.0 mi band	1.010	(0.016)		1.009	(0.006)	
		2.0 mi band	1.000	(0.008)		1.002	(0.002)	
		3.0 mi band	1.003	(0.004)		0.999	(0.002)	
III	On-sales (Model specification 3)	0.5 mi band	1.000	(0.008)		0.998	(0.004)	
		1.0 mi band	1.002	(0.006)		1.005	(0.002)	**
		2.0 mi band	1.001	(0.002)		0.999	(0.001)	
		3.0 mi band	1.001	(0.001)		1.000	(0.001)	
IV	On-sales - Restaurants & Eating Places (Model specification	0.5 mi band	1.003	(0.012)		0.999	(0.004)	
		1.0 mi band	1.002	(0.008)		1.007	(0.002)	**
		2.0 mi band	1.000	(0.003)		0.999	(0.001)	
		3.0 mi band	1.001	(0.002)		1.001	(0.001)	
V	On-sales - Bars & Taverns (Model specification 5b)	0.5 mi band	0.991	(0.027)		0.989	(0.018)	
		1.0 mi band	1.011	(0.022)		1.024	(0.010)	**
		2.0 mi band	1.011	(0.011)		1.000	(0.004)	
		3.0 mi band	1.000	(0.008)		0.999	(0.004)	
			MEN/CHIS					
I	Total alcohol sales licenses (Model specification 1)	0.5 mi band	0.994	(0.004)		1.007	(0.002)	**
		1.0 mi band	1.006	(0.002)	**	0.998	(0.001)	
		2.0 mi band	0.999	(0.001)		1.000	(0.000)	
		3.0 mi band	0.999	(0.001)		1.000	(0.000)	
II	Off-sales (Model specification 2)	0.5 mi band	0.979	(0.013)		1.010	(0.008)	
		1.0 mi band	1.000	(0.000)		0.999	(0.005)	
		2.0 mi band	0.995	(0.003)		1.001	(0.002)	
		3.0 mi band	0.998	(0.002)		1.000	(0.001)	
III	On-sales (Model specification 3)	0.5 mi band	0.995	(0.004)		1.009	(0.003)	**
		1.0 mi band	1.006	(0.002)	**	0.998	(0.001)	
		2.0 mi band	0.999	(0.001)		1.000	(0.001)	
		3.0 mi band	0.999	(0.001)		1.000	(0.000)	
IV	On-sales - Restaurants & Eating Places (Model specification	0.5 mi band	0.992	(0.006)		1.010	(0.003)	**
		1.0 mi band	1.009	(0.003)	**	0.998	(0.002)	
		2.0 mi band	0.998	(0.001)		1.000	(0.001)	
		3.0 mi band	0.999	(0.001)		1.000	(0.001)	
V	On-sales - Bars & Taverns (Model specification 5b)	0.5 mi band	1.001	(0.020)		1.036	(0.015)	*
		1.0 mi band	1.014	(0.014)		0.996	(0.008)	
		2.0 mi band	1.000	(0.006)		1.003	(0.003)	
		3.0 mi band	0.995	(0.005)		1.001	(0.003)	

Note: The asterisk (*) indicates significant at the 5% level (two-tailed test);
** significant at the 1% level (two-tailed test). Regressions are weighted.

Table 4.7: Simulated Prevalence of Problem Drinking in Los Angeles County

	Type of licenses	Problem Drinking Indicator	Alcohol availability	Prevalence of Problem Drinking in LACHS			
				Women		Men	
				Prevalence	95% C.I.	Prevalence	95% C.I.
I	Total on-sales	Heavy Episodic Drinking (Y2)	Median	0.116	(0.113, 0.118)	0.200	(0.197, 0.204)
			90th percentile	0.131	(0.128, 0.134)	0.210	(0.206, 0.214)
II		Riding with a Drinking Driver (Y4)	Median	0.033	(0.033, 0.034)	0.043	(0.041, 0.044)
			90th percentile	0.035	(0.034, 0.036)	0.049	(0.048, 0.051)
III	On-sale minor-restricted outlets	Heavy Episodic Drinking (Y2)	Median	0.111	(0.108, 0.113)	0.196	(0.192, 0.199)
			90th percentile	0.143	(0.140,0.146)	0.220	(0.216, 0.224)
IV		Riding with a Drinking Driver (Y4)	Median	0.029	(0.029, 0.030)	0.040	(0.039, 0.041)
			90th percentile	0.041	(0.040, 0.042)	0.055	(0.053, 0.057)

Note: Statistics are weighted.

Table 4.8: Random Intercept Hierarchical Model's Results for Women's Heavy Episodic Drinking

	Empty Model		Explanatory Model		Full Model	
Independent variables	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**	**Coef.**	**Std. Err.**
Individual characteristics						
Employed			0.17	0.16	0.16	0.16
Married or w/ partner			-0.44	0.15 **	-0.43	0.15 **
High school diploma			0.09	0.27	0.13	0.27
Some college			0.33	0.26	0.37	0.26
College and higher			0.32	0.28	0.31	0.28
Age 31-40			-0.18	0.17	-0.18	0.17
Age 41-50			-0.65	0.20 **	-0.66	0.20 **
Age 51-60			-1.31	0.26 **	-1.31	0.26 **
Age 61-70			-1.43	0.38 **	-1.47	0.38 **
Age over 70			-2.50	0.55 **	-2.52	0.55 **
Hshd income: $10K-20K			-0.29	0.26	-0.23	0.26
Hshd income: $20K-30K			-0.37	0.26	-0.35	0.26
Hshd income: $30K-40K			-0.35	0.28	-0.31	0.28
Hshd income: $40K-50K			-0.34	0.28	-0.30	0.28
Hshd income: $50K-75K			-0.10	0.26	-0.04	0.26
Hshd income > 75K			-0.07	0.24	-0.04	0.24
Non-Hispanic Black			-0.46	0.26	-0.48	0.26
Hispanic			-0.16	0.18	-0.17	0.18
Asian & pacific islander			-0.57	0.31	-0.59	0.31
Other race			-0.04	0.39	-0.10	0.40
Smoking			1.05	0.17 **	1.05	0.17 **
Census tract demographics						
Log of hshd median income			-0.21	0.23	-0.09	0.25
Number of hshds			0.00	0.00	0.00	0.00
Percentage of Blacks			-1.02	0.61	-0.87	0.61
Percentage of Whites			-0.55	0.42	-0.68	0.43
Measures of alcohol outlets						
Total licenses in census tract					0.02	0.01 *
Total licenses in 0.5 mi buffer					0.00	0.00
Total licenses in 1.0 mi buffer					0.00	0.00
Total licenses in 1.5 mi buffer					0.00	0.00
Intercept	-1.37	0.08 **	1.39	2.44	-0.07	2.68
Intraclass correlation ICC	0.06	0.05	0.05	0.05	0.05	0.05

Note: * indicates significant at the 5% level (two-tailed test); ** significant at the 1% level (two-tailed test). Results are produced by Stata/SE 9.0 in the xtlogit routine.

Table 4.9: Sensitivity Analysis - Men's Smoking and Minor-Restricted Outlets

Logistic regression	Number of obs:	2648
	Wald chi2(28):	76.31
	Prob > chi2:	0
Log pseudolikelihood = -1369.4971	Pseudo R2:	0.0388

Smoking	OR	Std. Err.	z	P>|z|	95% CI	
Employed	1.020	0.149	0.140	0.891	0.767	1.357
Married	0.683	0.079	-3.310	0.001	0.545	0.856
Highschool Diploma	1.112	0.199	0.590	0.555	0.782	1.580
Some College	0.920	0.169	-0.450	0.652	0.642	1.320
College or Higher	0.542	0.108	-3.060	0.002	0.367	0.803
Age31-40	0.952	0.144	-0.320	0.747	0.708	1.281
Age41-50	0.963	0.157	-0.230	0.818	0.699	1.326
Age51-60	1.220	0.219	1.110	0.269	0.858	1.734
Age61-70	0.679	0.175	-1.500	0.133	0.410	1.125
Age71 & older	0.302	0.099	-3.640	0.000	0.159	0.576
Income group 2	1.061	0.213	0.300	0.767	0.716	1.572
Income group 3	0.912	0.186	-0.450	0.652	0.612	1.360
Income group 4	1.256	0.269	1.070	0.286	0.826	1.911
Income group 5	1.098	0.242	0.420	0.673	0.712	1.691
Income group 6	1.149	0.233	0.680	0.495	0.771	1.710
Income group 7	0.831	0.168	-0.910	0.361	0.560	1.236
Black	1.084	0.229	0.380	0.703	0.716	1.640
Hispanic	0.713	0.108	-2.230	0.026	0.529	0.960
Asian Pacific Islander	1.393	0.241	1.920	0.055	0.993	1.955
Other Race	0.811	0.310	-0.550	0.584	0.384	1.716
Tract median Hshd Income	0.722	0.150	-1.570	0.115	0.481	1.083
Tract number of Hshd	1.000	0.000	0.110	0.913	1.000	1.000
Percent Black in Tract	0.654	0.293	-0.950	0.343	0.272	1.575
Percent White in Tract	1.569	0.514	1.380	0.169	0.826	2.983
Type 42 & 48 in Tract	0.995	0.055	-0.090	0.926	0.892	1.110
Type 42 & 48 in 0.5 mi buffer	0.993	0.027	-0.270	0.790	0.942	1.047
Type 42 & 48 in 1.0 mi buffer	1.001	0.018	0.030	0.974	0.966	1.037
Type 42 & 48 in 1.5 mi buffer	1.008	0.014	0.590	0.554	0.981	1.036

Note: Regression are weighted.

Table 4.10: Comparing Characteristics of Respondents with and without Census Tract Information in LACHS

Variable	Respondents **without** census tract information			Respondents **with** census tract information			Difference	Stat
	Obs	Mean (A)	Std. Dev.	Obs	Mean (B)	Std. Dev.	(B) - (A)	signfc
Any alcohol past 30 days	1697	0.465	(0.50)	6155	0.565	(0.50)	10.05%	***
Average # of drinks per day	816	2.288	(2.31)	3478	2.393	(2.40)	0.10	
Frequency of drinking days	830	6.384	(8.07)	3511	7.112	(8.16)	0.73	*
Excess alcohol consumption	809	0.035	(0.18)	3460	0.044	(0.20)	0.90%	
Heavy drinking episodes	811	0.255	(0.44)	3493	0.292	(0.45)	3.68%	*
Driving after drinking	841	0.040	(0.20)	3529	0.043	(0.20)	0.34%	
Riding with a drinking driver	1683	0.041	(0.20)	6144	0.038	(0.19)	-0.25%	
Current smoker	1704	0.157	(0.36)	6160	0.178	(0.38)	2.12%	*
Age 21-30	1704	0.202	(0.40)	6160	0.246	(0.43)	4.41%	*
Age 31-40	1704	0.212	(0.41)	6160	0.238	(0.43)	2.57%	
Age 41-50	1704	0.192	(0.39)	6160	0.199	(0.40)	0.67%	
Age 51-60	1704	0.140	(0.35)	6160	0.135	(0.34)	-0.58%	
Age 61-70	1704	0.100	(0.30)	6160	0.085	(0.28)	-1.45%	*
Age over 70	1704	0.154	(0.36)	6160	0.098	(0.30)	-5.62%	***
Hshd income <$10K	1704	0.413	(0.49)	6160	0.214	(0.44)	-19.90%	***
Hshd income: $10K-20K	1704	0.184	(0.39)	6160	0.174	(0.38)	-0.98%	*
Hshd income: $20K-30K	1704	0.105	(0.31)	6160	0.134	(0.34)	2.92%	**
Hshd income: $30K-40K	1704	0.077	(0.27)	6160	0.097	(0.30)	2.02%	*
Hshd income: $40K-50K	1704	0.055	(0.23)	6160	0.089	(0.29)	3.37%	***
Hshd income: $50K-75K	1704	0.069	(0.25)	6160	0.122	(0.33)	5.28%	***
Hshd income > 75K	1704	0.097	(0.30)	6160	0.170	(0.38)	7.28%	***
Married or w/ partner	1668	0.502	(0.50)	6142	0.469	(0.50)	-3.28%	*
No highschool diploma	1704	0.338	(0.47)	6160	0.220	(0.41)	-11.79%	***
High school diploma	1704	0.213	(0.41)	6160	0.215	(0.41)	0.27%	
Some college	1704	0.227	(0.42)	6160	0.274	(0.45)	4.68%	**
College and higher	1704	0.212	(0.41)	6160	0.290	(0.45)	7.77%	**
White	1704	0.406	(0.49)	6160	0.508	(0.50)	10.25%	***
Black	1704	0.108	(0.31)	6160	0.099	(0.30)	-0.86%	
Hispanic	1704	0.310	(0.46)	6160	0.275	(0.45)	-3.52%	***
Asian & pacific islander	1704	0.182	(0.39)	6160	0.134	(0.34)	-4.85%	***
Other race	1704	0.020	(0.14)	6160	0.014	(0.12)	-0.67%	*

Note: * indicates significance at the 5%, ** at 1% level, and *** 0.1% level (two-tailed test)

Appendix 1: Multi-level Model Specification

The *empty model* includes only the intercept which is allowed to vary across neighborhoods (random intercept model). The estimated unconditional intraclass correlation (ICC) from this model indicates the proportion of the variation of the drinking behavior *between* neighborhoods (before adjusting for any other factors) as opposed to the total variation (which is the sum of *between* neighborhood variation and *within* neighborhood variation). The *explanatory model* is estimated by adding individual characteristics and census tract sociodemographics to the *empty model*. The *full model* is estimated by adding measures out alcohol outlets to the *explanatory model*. These models can be summarized as follows.

(1) Empty model: $Y_{ij} = \beta_{0j} + r_{ij}$

where $\beta_{0j} = \gamma_{00} + u_{0j}$

Y_{ij} is a measure of a drinking behavior for individual i in neighborhood j;

β_{oj} is a neighborhood specific mean, composed of γ_{00} and $u_{0j;}$

γ_{00} is the grand mean of the outcome in the population;

u_{0j}, is a neighborhood specific random deviation from the grand mean, assumed to be distributed $N(0,\tau_{00})$;

r_{ij} is an individual specific random error, assumed to be distributed $N(0,\sigma^2)$;

σ^2 is the *between* neighborhood variance;

τ_{00} is the *within* neighborhood variance;

The intra-class correlation ICC: $\rho = \dfrac{\tau_{00}}{\tau_{00} + \sigma^2}$

(2) Explanatory model: $Y_{ij} = \beta_{0j} + \beta_{01} X_{ij} + \beta_{02} N_j + r_{ij}$

(3) Full model: $Y_{ij} = \beta_{0j} + \beta_{01} X_{ij} + \beta_{02} N_j + \beta_{03} O_{ij} + r_{ij}$

where X_{jj} represents a vector of individual i's characteristics;

N_j represents a vector of census tract-level sociodemographics in neighborhood j;

O_{ij} represents a vector of variables measuring alcohol outlets in neighborhoods – our key independent variables;

Comparing the *within* neighborhood variance, τ_{00}, estimated from model (2) to that of model (1) provides the reduced proportion of variation in drinking behavior due to the inclusion of individual and neighborhood sociodemographic characteristics. Similarly, comparing τ_{00}, estimated from model (3) to that of model (2) gives the percent of reduction in the variation in drinking behavior due to the availability of alcohol outlets in the neighborhoods. Estimated coefficients β_{03} indicate whether alcohol outlets are associated with the drinking behavior under consideration. These models are implemented by Stata in the xtlogit routine for dichotomous outcomes.

The intra-class correlation ϱ_1 estimated from model (1) indicates the percent of variation in the outcomes before adjusting for any other factors. Similarly, the intra-class correlation ϱ_2 estimated from model (2) shows the variation after controlling for individual and tract-level sociodemographics. If ϱ_1 is large, say 20%, but ϱ_2 is minimal, say 2%, it means the added variables into the explanatory model contributed to this reduction of variation, and that alcohol outlets (and other uncontrolled factors) are left with little explanatory power.

Chapter 5: Weight Gain Trends across Sociodemographic Groups in the United States[5]

Abstract

Objectives: To better understand health disparities, we compared US weight gain trends across sociodemographic groups between 1986 and 2002.

Methods: We analyzed mean and 80th-percentile body mass index (BMI), calculated from self-reported weight and height, for subpopulations defined by education, relative income, race/ethnicity, and gender. Data were from the Behavioral Risk Factor Surveillance System, a random-digit-dialed telephone survey (total sample= 1.88 million adult respondents).

Results: Each sociodemographic group experienced generally similar weight gains. We found no statistically significant difference in increase in mean BMI by educational attainment, except that individuals with a college degree gained less weight than did others. The lowest-income group gained as much weight on average as the highest-income group, but lowest-income heavier individuals (80th percentile of BMI) gained weight faster than highest-income heavier individuals. We found no differences across racial/ethnic groups except that non-Hispanic Blacks gained more weight than other groups. Women gained more weight than men

Conclusions: We found fewer differences, especially by relative income and education, in weight gain across subpopulations than we had expected. Women and non-Hispanic Blacks gained weight faster than other groups.

[5] Truong KD, Strum R. Weight gain trends across sociodemographic groups in the United States. Am J Public Health. 2005 Sep; 95(9):1602-6. Reprinted with permission from the American Public Health Association.

INTRODUCTION

While large segments of the American population are either overweight (body mass index [BMI]>25) or obese (BMI≥30), disparities exist in the prevalence of overweight and obesity across population subgroups defined by race/ethnicity, gender, age, or socioeconomic status. A larger proportion of individuals are overweight or obese among lower-educated groups, Blacks, and Mexican Americans than among other sociodemographic groups, and socioeconomic differences in obesity rates tend to be larger for women than for men (Mokdad et al., 2003; Flegal et al., 2002; National Center for Health Statistics, 1999).

Although sociodemographic differences in the prevalence of unhealthy weight contribute to health disparities, it is not clear how the current obesity epidemic has contributed to these disparities. The National Health and Nutrition Examination Survey (NHANES), the benchmark for objectively measured national trends, shows no statistically significant differences in increasing obesity rates among racial/ethnic groups for men (Flegal et al., 2002). This finding, however, may be primarily a consequence of insufficient statistical power for subgroup comparison; although a highly significant increase in severe obesity has occurred for the full population, this increase is not statistically significant for most individual subpopulations. Data from the Behavioral Risk Factor Surveillance System (BRFSS) show significant differences across racial/ethnic groups. However, the direction (widening or narrowing) of the disparities seen depends on the cutpoint used to define unhealthy weight (BMI = 25, 27, or 30) and the type of changes (i.e., absolute vs relative) being considered (Mokdad et al., 2003; Flegal et al., 2002; National Center for Health Statistics, 1999; Mokdad et al., 1999).

Plausible hypotheses have been developed to explain trends of widening or narrowing health disparities related to unhealthy weight. One intriguing theory focuses on the economics of food supply, taking into consideration that individuals with limited financial resources must choose energy-dense foods, which in turn is likely to encourage excessive energy intake (Drewnowski and Specter, 2004; Drewnowski et al., 2004). This process could result in widened disparities across income groups, given that the prices of less energy-dense products, such as fresh produce, have increased more rapidly than the consumer price index over the past 2 decades, whereas the prices of more energy-dense products, such as fats and sweets, have increased slower than the consumer price index (Sturm 2005a,b). If the differential costs of diets constitute a primary pathway to disparities in weight gain, differential weight gain would be expected to occur across income groups, but not necessarily by education or race/ethnicity, after adjustment for income.

Another possible explanation for increasing disparities is that higher-educated groups tend to make health-improving behavior changes in response to new knowledge more quickly than do lower-educated groups, as has occurred in the case of smoking (Pierce et al., 1989). Arguments also have been made supporting a narrowing of weight-related disparities over time. Suburban sprawl has been associated with higher rates of obesity, less walking, and chronic conditions related to obesity, after control for individual sociodemographic characteristics, but neighborhoods with characteristics of suburban sprawl (low population density, poorly connected streets, single-mode land use) tend to be characterized by higher income and fewer minorities than are urban neighborhoods (high population density, better connected streets, mixed land use) (Ewing et al., 2003; Sturm and Cohen, 2004; Saelens at al., 2003a,b). It is also possible that factors leading to differential weight gain across population subgroups are less important than secular changes that affect all groups, such as motorization, suburbanization, and increased food availability. If that is so, weight would be expected to increase similarly across groups.

We studied trends in weight gain through analysis of BRFSS data for 1986 through 2002. We focused on changes in BMI (mean and 80th percentile) among different sociodemographic groups. We tried to determine whether population differences are primarily related to education, race/ethnicity, relative income, or gender.

METHODS

Data

We used data from the 1986-2002 BRFSS, a cross-sectional telephone survey of noninstitutionalized adults. The BRFSS is a standard data set for tracking obesity and diabetes rates, as well as other health behaviors, over time (Mokdad et al., 2001; Mokdad et al., 1999; Nelson et al., 2002); study details are available at the Centers for Disease Control and Prevention Web site (Centers for Disease Control and Prevention, 2004). Table 5.1 presents descriptive statistics from the data sets used for our analyses, which included 17 years of the BRFSS and 1,879,862 observations. To allow a comparison with the effect of relative income, we also generated a subsample of lowest-income vs. highest-income households.

Dependent Variable

The primary dependent variable was individual BMI, defined as weight in kilograms divided by the square of height in meters. BMI was calculated from self-reported weight and height and is therefore subject to the well-known biases of self-report data (Palta et al., 1982; Stunkard and Albaum, 1981; Kuczmarski et al., 2001). Because the level of underreporting tends to increase with actual weight and the weight of the total population has increased, this bias may lead to underestimation of increases in BMI across all groups. In addition to mean BMI, 80th-percentile BMI was included in the analysis because weight gain in this heavier subgroup may differ from mean weight gain. On the basis of 2000-2002 BRFSS data, the 80th percentile corresponds to a BMI of 30.13.

Independent Variables

Explanatory variables included calendar year, education (no high school diploma, high school diploma, some college, and college graduation), race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, and other), gender, marital status (married or member of an unmarried couple vs. other), employment status (working for wages or self-employed vs. other), smoking status (current smokers [those who smoke every day and have smoked at least 100 cigarettes in their lives] vs. other), age group (in 5-year intervals), and state of residence (to control for changing survey participation by states over time).

Time trend was measured by calendar year. To allow for nonlinear changes in weight gain over time, we used linear spline with knots at 1991 and 1996 (different amounts of weight gain for the periods 1986-1990, 1991-1995, and 1996-2002). To estimate the BMI trend by education, race/ethnicity, and gender, we included in the model terms to capture interactions between year and education, year and race/ ethnicity, and year and gender. These interaction terms were the key independent variables that predicted differential increases in BMI over time across the study groups.

Ideally, we would have included income in testing the separate effects of income, education, race/ethnicity, and gender. However, the BRFSS includes only 7 broad categories based on nominal income. Because the meaning of these categories changes over time, and they cannot be adjusted for inflation, we could not include income in the model that predicts BMI trends by education, race/ ethnicity, and gender. The exclusion of income from the model probably produces an overestimation of educational effects on BMI gains because of the positive relationship between income and education and the negative relationship between income and BMI (evidenced by our BRFSS data). Similarly, this exclusion could increase the gap between minority groups and non-Hispanic Whites by attributing an economic factor to the race/ethnicity effects.

To test the relevance of income, we focused on a subsample of the data representing the lowest- and highest-income groups for each year. BRFSS data provide income categories, not actual income, for each respondent. The percentage of people in each of the 7 income categories in BRFSS data varies from one year to another, substantially so in some years. To generate a subsample of data containing the lowest and highest income groups with the percentages roughly constant over the study years, it was sometimes necessary to combine BRFSS income categories. For instance, the 2 highest income categories for 1986 (13.83% and 7.29%) were combined to produce the new highest income group of 21.12%, roughly comparable to the lowest income category for 1986 (19.97%). Income categories from BRFSS data were combined for the years where there were considerable differences in the percentages. As a result, there are 676 830 observations in this subsample. This reclassification allowed us to obtain a crude estimate of the effects of relative income. The results for BMI trends across the 2 relative-income groups were based on this subsample.

Statistical Methods

We used ordinary least squares regression to estimate the conditional mean BMI and least absolute deviation regression to estimate the 80th-percentile BMI across sociodemographic groups. Regressions were weighted to control for differential sampling probabilities across years, states, and sociodemographic groups that may not be fully accounted for by the included independent variables.

For the analysis of education, race/ethnicity, and gender, the independent variables include the linear time spline, education and its interactions with time, race/ethnicity and its interactions with time, gender and its interactions with time, marital status, smoking status, employment status, age group, and state dummy variables. For the analysis of relative income, we used the subsample of the highest- and lowest-income groups and added relative income and its interactions with time to the same model specification for education, race/ethnicity, and gender.

Tests were based on the individual-level regression model for the null hypothesis of no differences in BMI gain across sociodemographic groups. Because the time trend was specified as a linear spline with 2 knots, 3 time variables were used to represent the 3 periods. The number of interaction terms between any sociodemographic variable and time is thus 3. Joint tests for these interaction terms were conducted. The following example may help to clarify our hypothesis testing. Assume that gender is a dummy variable. Year 1, year 2, and year 3 are time variables representing the 3 periods divided by the 2 knots. The 3 interaction terms are thus gender with year 1, gender with year 2, and gender with year 3. If male gender was the reference group and if all 3 interaction terms simultaneously equaled 0, this would indicate that, in each and every period, weight gain was the same for men and women, which would confirm the null hypothesis.

Because of numerous comparisons, we restricted our analysis to results that were statistically significant at $P<.001$. Even at this statistical significance level, there could be statistically significant findings that are un-important because the sample size is large and high statistical power is able to detect even minute differences. To plot the weight gain trends after adjustment for changes in other confounding factors, we used population characteristics for the year 2002 as follows. First, we estimated the model coefficients, using the full sample for the model without income and the subsample for the model with relative income. Second, we predicted the conditional mean BMI for every respondent in 2002. Third, we used all covariates of the respondents for 2002 except for the time value to predict the conditional mean BMI for the respondents from the other years. For instance, to predict conditional mean BMI for the respondents from 1986, we retained the observations for 2002 but replaced the year value with 1986. Last, after the prediction, we estimated the weighted yearly average BMI for every year from 1986 to 2002. Except for the first step, this process was repeated for each sociodemographic group. We performed the same estimation for 80th-percentile BMI (data not shown).

RESULTS

Body Mass Index Trend Across Education Groups

Figure 5.1 shows the mean BMI across education groups for each year. For any year, lower educational achievement was associated with higher BMI, but the curves were essentially parallel in the no-high-school-diploma group, the high-school-diploma group, and the some-college group. Only in the college-graduation group was weight gain statistically significantly smaller, although the total difference in weight gain among the groups over the study period was not large: 1.74 BMI units for the college group vs. 2.09 BMI units for the no-high-school-diploma group. The average person in the high-school-diploma group, the some-college group, and the college-graduation group passed from normal to overweight status (BMI=25) in 1988, 1990, and 1997, respectively. We can extrapolate that the average person in the no-high-school-diploma group became overweight in 1982. The BMI gap between the lowest-education and the highest-education group was about 14 years; that is, unless trends change, the average BMI of the college-graduation group will reach the level of the current average BMI of the no-high-school-diploma group in 14 years. For 80th-percentile BMI, the no-high-school-diploma group gained less weight than the high-school-diploma group or the some-college group and about the same amount of weight as the college-education group.

Body Mass Index Trend Across Relative-Income Groups

Figure 5.2 confirms that for every year, BMIs were higher for the lowest-income group than for the highest-income group. From 1986 to 1991, the highest-income group gained slightly less weight than the lowest-income group, but the 2 groups exhibited parallel trends from 1992 to 2002, and we found no statistically significant difference in increased BMI between the 2 groups. The BMI gap between the lowest-income and highest-income groups is approximately 7 years; that is, the average BMI of the highest-income group will reach the current average BMI of the lowest-income group in 7 years.

The 80th-percentile BMI curves of the lowest- and highest-income groups were parallel from 1986 to 1991, but from 1992 to 2002 there was a statistically significant divergence, with the lowest-income group gaining more weight than the highest-income group.

Body Mass Index Trends Across Racial/Ethnic and Gender Groups

BMI trends among non-Hispanic Whites, Hispanics, and individuals of "other" race/ethnicity are essentially parallel, but non-Hispanic Blacks gained weight faster: 2.79 BMI units over 16 years, compared with 2.0 BMI units for non-Hispanic Whites, 2.17 BMI units for Hispanics, and 2.26 BMI units for persons of "other" race/ethnicity (P<.001), as shown in Table 5.2. BMIs for non-Hispanic Blacks, which were already high in 1986, became higher over time in both absolute terms and in terms relative to other racial/ethnic groups. Excluding income in the model that predicts BMT gain across racial/ethnic groups may overestimate this differential weight gain, but probably not dramatically, because we found no significant income effect on mean weight gain in the 2 periods 1991-1995 and 1996-2002.

On average, women have lower BMIs than men, but they gained weight faster. The BMI gap between women and men is about 6 years; that is, in 6 years, women can be expected to attain the BMI now current among men. However, women's and men's BMIs are converging. From 1986 to 2002, women gained 2.4 BMI units and men gained 1.82 BMI units. If that differential weight gain trend continues, women's average BMI would match men's average BMI in 26 years.

The trend of increasing weight gain among both non-Hispanic Blacks and women was exacerbated at the 80th percentile of BMI. At that percentile, the BMI gap between women and men is only about 2 years, and women's average BMI could match men's average BMI in about 15 years.

DISCUSSION

Weight gain among Americans is more uniform than one might expect on the basis of cross-sectional differences in the prevalence of obesity among subpopulations. Our findings confirm previous studies (Mokdad et al., 2001; Flegal et al., 2002; Mokdad et al., 1999) showing that average BMI is always higher for lower-education, lower-income groups and for non-Hispanic Blacks. However, our study also shows that, for the past decade and even longer, average weight gain has not varied by educational level, although a college degree was associated with lower weight gain. Few differences exist in average weight gain between lowest- and highest-income individuals after controlling for other characteristics, although heavier individuals (80th percentile of BMI) in the lowest-income group gain more weight than do heavier individuals in the highest-income group.

Increases in BMI were similar for most racial/ethnic groups, except for non-Hispanic Blacks, whose mean weight increased the fastest. In 2002, the difference in average BMI in our study was 1.83 units between non-Hispanic Blacks and non-Hispanic Whites, 1.01 units between the lowest- and highest-income groups, and 1.83 units between the no-high-school-diploma group and the college-graduation group. As Table 5.2 shows, BMI gain from 1986 to 2002 differed by 0.79 units between non-Hispanic Blacks and non-Hispanic Whites, by 0.35 units between the no-high-school-diploma group and the college-graduation group, and by 0.53 units between the lowest- and highest-income groups. The difference in BMI between non-Hispanic Blacks and the other racial/ethnic groups is the clearest and most important evidence of widening disparities among subpopulations.

Although mean BMIs are lower for women than for men, women are gaining weight faster than men. If this trend continues, women will eventually overtake men at the 80th percentile of BMI-the level that entails the highest risk for chronic disease-and assume an increasing burden of obesity-related health problems. In fact, whereas the latest estimates of obesity rates based on self-reported height and weight still show lower obesity rates for women than for men (Mokdad et al., 2001, 1999; Saelens et al., 2003; Nelson et al., 2002) this difference no longer exists for rates based on objectively measured height and weight (Flegal et al., 2002).

Two groups of factors affect weight trends. The first group is factors common to all sociodemographic groups, such as motorization, suburbanization, and increased food availability. The effects of these common factors, however, can vary by characteristics such as education, relative income, and race/ethnicity. Motorization and suburbanization, for example, are common to the whole population, but their adverse effects might be larger for higher-income communities and smaller for minority neighborhoods (Ewing et al., 2003; Sturm and Cohen, 2004; Saelens et al., 2003a,b). The second group is factors that may affect some subpopulations but not others. For instance, women's increasing participation in the workforce may have a differential effect on their weight trend relative to that of men. The pattern of weight gain we found captures the net effect of all factors, and probably the interaction of these factors. In-depth studies are needed to quantify the differential effects of specific factors and the numerous changes in the living environment. Interventions need to take into account the mechanisms by which various factors affect the weight gain of each sociodemographic group.

Nevertheless, our most striking finding is probably the similarity in weight gain across groups, which indicates that hypotheses successful in explaining weight differences across sociodemographic groups may be less successful in generating policies to stem the obesity epidemic. However, we found noticeable differences in weight gain that indicate the need for strategies targeted at certain subgroups, particularly women and Blacks.

Table 5.1: Sociodemographic Characteristics: Behavioral Risk Factor Surveillance System 1986-2002

	% in Sample (SD)	BMI, 1986 - 1990 Mean (SD)	BMI, 1986 - 1990 80th Percentile (95% CI)	BMI, 1991 - 1995 Mean (SD)	BMI, 1991 - 1995 80th Percentile (95% CI)	BMI, 1996 - 2002 Mean (SD)	BMI, 1996 - 2002 80th Percentile (95% CI)
Education							
No High School Diploma	14.4	25.7	29.2	26.2	29.9	27.1	31.2
	(35.1)	(4.9)	(29.1, 29.2)	(5.1)	(29.8, 30.0)	(5.7)	(31.1, 31.2)
High School Diploma	32.7	24.8	27.9	25.5	28.9	26.5	30.2
	(46.9)	(4.4)	(27.9, 28.0)	(4.7)	(28.8, 28.9)	(5.3)	(30.1, 30.2)
Some College	26.9	24.4	27.4	25.2	28.3	26.2	29.9
	(44.3)	(4.2)	(27.3, 27.4)	(4.7)	(28.3, 28.3)	(5.2)	(29.8, 29.9)
College Graduation	25.9	24.2	26.7	24.8	27.5	25.6	28.8
	(43.8)	(3.8)	(26.6, 26.9)	(4.1)	(27.5, 27.5)	(4.6)	(28.7, 28.8)
Race/Ethnicity							
Non-Hispanic White	76.6	24.6	27.5	25.2	28.3	26	29.5
	(42.3)	(4.2)	(27.4, 27.5)	(4.6)	(28.3, 28.3)	(5.0)	(29.5, 29.5)
Non-Hispanic Black	9.3	25.8	29.6	26.7	30.7	27.8	32.2
	(29.1)	(5.0)	(29.5, 29.8)	(5.3)	(30.5, 30.7)	(5.9)	(32.1, 32.3)
Hispanic	9.8	25	28.1	25.7	28.9	26.8	30.2
	(29.7)	(4.3)	(27.9, 28.2)	(4.6)	(28.7, 29.0)	(5.2)	(30.1, 30.2)
Other Race	4	23.5	27.1	24.2	28	25.1	29.4
	(19.6)	(4.0)	(26.8, 27.3)	(4.4)	(27.8, 28.2)	(4.9)	(29.3, 29.6)
Gender							
Women	51	24	27.4	24.7	28.3	25.7	29.8
	(50.0)	(4.7)	(27.4, 27.4)	(5.1)	(28.3, 28.3)	(5.6)	(29.8, 29.8)
Men	49	25.4	28.1	26	28.7	26.8	29.9
	(50.0)	(3.8)	(28.0, 28.1)	(4.1)	(28.7, 28.8)	(4.6)	(29.8, 30.0)
Income							
Lowest Income	31.6	25	28.8	25.8	29.5	26.8	31.2
	(46.5)	(5.1)	(28.7, 29.0)	(5.5)	(29.5, 29.6)	(6.1)	(31.2, 31.2)
Highest Income	68.4	24.5	27.4	25.1	28.1	26	29.3
	(46.5)	(4.2)	(27.4, 27.5)	(4.2)	(28.0, 28.1)	(4.6)	(29.2, 29.3)

	1986 - 2002	1986 - 1990	1991 - 1995	1996 - 2002
Age, mean	44.4	43.3	43.9	45.2
	(17.6)	(17.8)	(17.6)	(17.5)
Married, %	62.4	63.2	62.9	61.8
	(48.4)	(48.2)	(48.3)	(48.6)
Woking, %	63	63.2	62.6	63.2
	(48.3)	(48.2)	(48.4)	(48.2)
Smoking, %	20.3	24.7	21.1	17.9
	(40.2)	(43.1)	(40.8)	(38.4)

Note: N = 1,879,862. Descriptive statistics of the two relative income groups were based on a subsample of data with 676,830 observations. Standard deviations and 95 percent confidence interval are in parentheses. Except for the 80th percentile BMI, all other statistics are weighted and nationally representative.

Table 5.2: Increase in Body Mass Index by Sociodemographic Group

	Total Increase in BMI during 1986-2002	
Sociodemographic Group	**Average BMI**	**80th percentile BMI**
Education		
No high school diploma	2.09	2.79*
High school diploma (Ref. Group)	2.31	3.17
Some-college	2.30	3.21
College Graduation	1.74*	2.46*
Income		
Lowest income	2.19*	3.38*
Highest income (Ref. Group)	1.66	2.24
Race/Ethnicity		
Non-Hispanic White (Ref. Group)	2.00	2.84
Non-Hispanic Black	2.79*	3.51*
Hispanic	2.17	2.86
Other	2.26	3.14
Gender		
Female	2.40*	3.34*
Male (Reference Group)	1.82	2.50

Note: The asterisk (*) indicates that the group's BMI gain is statistically significantly different from that of the reference group at 0.1% level.

Figure 5.1: Trends in Mean Body Mass Index by Education

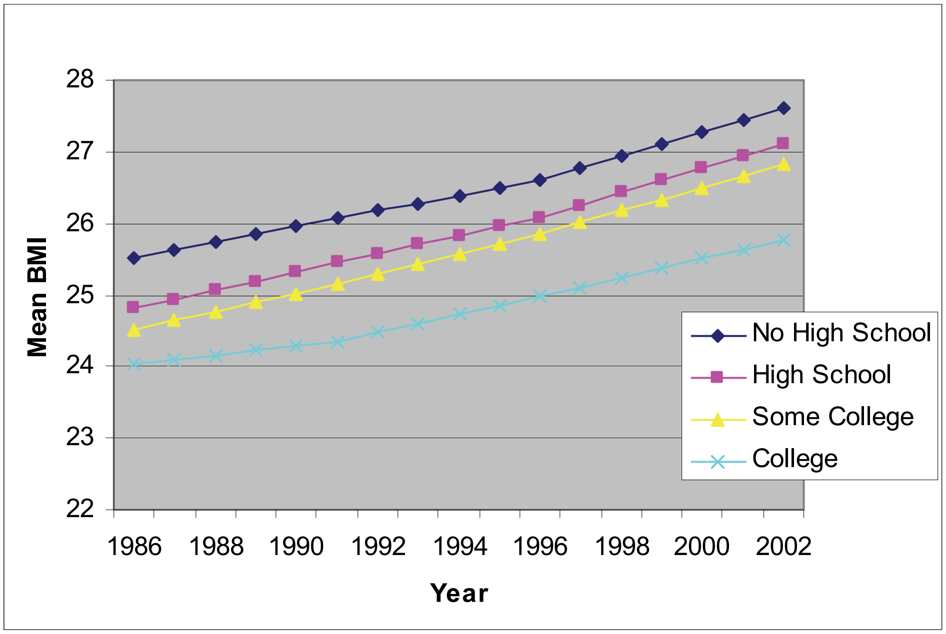
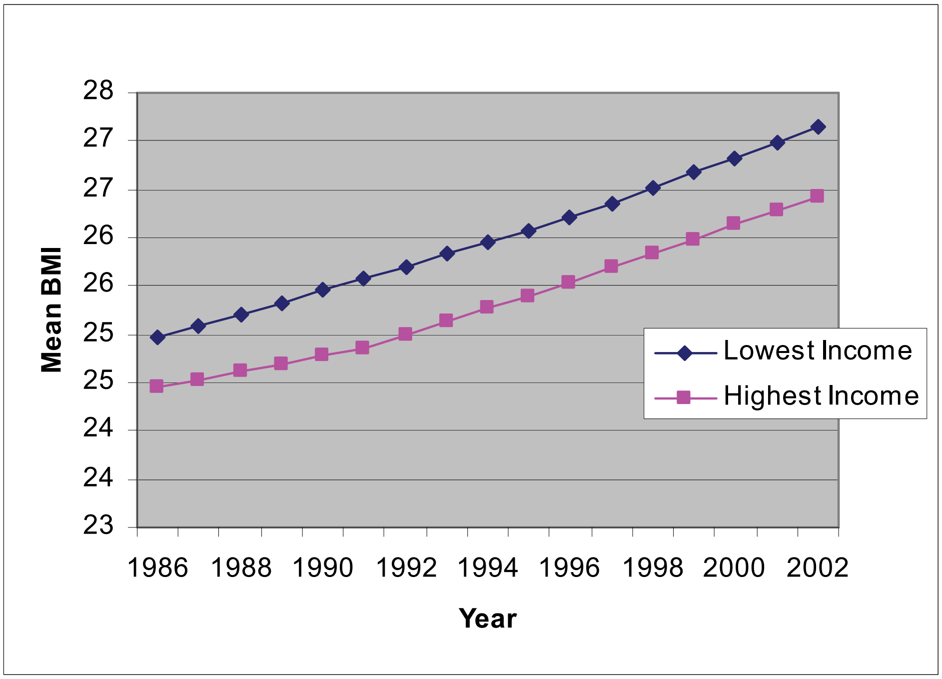


Figure 5.2: Trends in Mean Body Mass Index by Relative Income



Chapter 6: Do Food Environments Contribute to the Obesity Epidemic?

Abstract

Researchers are increasingly aware of contextual influences, including the role of the built environment, on the increasing prevalence of obesity. Using data from a recent comprehensive study of food landscape in California and the California Health Interview Survey 2005, I find a consistent and significant relationship between retail food environment and individual body mass index (BMI) status.

Retail food environment index (RFEI), defined as the ratio of the combined number of convenience stores and fast-food restaurants to the combined number of supermarkets and produce vendors, is 4.18 statewide and varies substantially across California counties. There is also large variation in county-level prevalence of obesity. Counties that are more dominated by fast food restaurants and convenience stores have higher unadjusted rates of obesity and vice versa. After controlling for individual and contextual factors, RFEI is still a statistically significant predictor of individual BMI gain ($p < 0.001$), overweight status ($p < 0.001$) and obese status ($p < 0.001$). Magnitude of the effect is non-trivial and stronger for women. Results from a counterfactual simulation in which I allows the current statewise RFEI to increase from 4:18 to 5:18 show that women would gain on average 0.22 unit of BMI compared to 0.12 for men. Prevalence of overweight (BMI $\geq$ 25) would increase from 45.63% to 47.68% among women and 65.01% to 66.54% among men. And rate of obesity (BMI $\geq$ 30) would increase from 18.73% to 20.22% among women and 21.54% to 22.24% among men.

This study reports a robust link between food landscape and individual BMI status. It supports the call for improving supply of and access to more healthy food for the population in the endeavor of curbing the obesity epidemic in California.

INTRODUCTION

Obesity and its profound effects on individual health and healthcare system have become one of the greatest public health concerns in the U.S. Annual national obesity-attributable medical expenditures are estimated at $75 billion, and about one-half of these expenditures are paid by Medicare and Medicaid (Finkelstein et al., 2004). The Department of Health and Human Services has made preventing and curbing the obesity epidemic one of its top action priorities (DHHS, 2000). Obesity is highly prevalent in California. In 2005, California had about 5.7 million obese adults (defined as those age 18 or older with a body mass index ≥ 30), or about 21.2% of its adult population (UCLA Center for Health Policy Research, 2007).

Researchers are increasingly aware of contextual influences, including the role of the built environment, on the excessive prevalence of obesity (Cunningham and Michael, 2004; Papas et al., 2007). Local food supply is an important aspect of the built environment that has been examined in relation to nearby residents' dietary intakes (Cheadle et al., 1991, 1993; Edmonds et al., 2001; Laraia et al., 2004; Rose and Richards, 2004), and weight outcomes (McCrory et al., 1999; Thompson et al. 2004, Maddock, 2004; Taveras et al., 2005; Duffey et al., 2007; Wang et al., 2007). Evidence of plausible links between food environments and individual health outcomes is, however, mixed. Limited in geographical coverage, previous studies mostly investigate one food outlet type or presence of certain combinations of food stores rather than all sources of food outlets in local areas. Some find that availability of fruits and vegetables is associated with consumption and the presence of supermarkets is associated with a lower prevalence of obesity (Edmonds et al., 2001; Morland et al., 2006). However, others find no association between proximity to supermarkets and reduced obesity risk (Wang et al., 2007). While square miles per fast-food restaurant and residents per restaurant explain some between-state variation in obesity prevalence (Maddock 2004), another study find that fast-food restaurants nearby home or work are not associated with eating fast-food or individual body mass index (Jeffery et al., 2006). There exists a related literature that links community characteristics to the location of food store types (Morland et al., 2002; Zenk et al., 2005; Austin et al., 2005; Moore and Roux, 2005; Powell et al., 2007; Cummins et al., 2005; Block et al., 2004). The general finding is that predominantly minority and low-income neighborhoods contain fewer healthy food outlets. These studies, however, do not consider individual health outcomes.

In my judgment, there are three key limitations in the literature of the food environments and individual health studies, namely, limited sample data, use of predefined geographical units, and partial focus on one type of food outlets. A few examples can be given. Cheadle et al. had a sample of only 12 communities when examining community-level grocery store environment and individual dietary practices (1991, 1993). Edmonds et al. investigated the link between median family income and fruit, juice, and vegetable availability in grocery stores, restaurants, and homes of African-American Boy Scouts ages 11-14 in only 11 census tracts (2001). McCrory et al. had a sample of 73 adults when looking into the frequency of consuming restaurant food and body fatness (1999). The shortcomings of using pre-defined administrative areas to proxy neighborhoods were discussed in the previous chapters, and several studies cited in this paragraph used census tracts or zip codes as unit of analysis for food outlets. The most important limitation of this literature in my opinion is the partial analysis of food stores. There a several studies attempting to connect the geographic distribution of fast food restaurants relative to neighborhood sociodemographics (Block et al., 1995; Maddock, 2004; Macdonald et al., 2006). It however remains unclear if the absolute or relative availability of food outlet types in local areas matters when it comes to the consumption decision. Studies that construct comprehensive measures of food environments and link them to individual health behaviors or outcomes are rare. Morland and her colleagues' studies are among a few that link residents' diets to a *comprehensive* measure of supermarkets, grocery stores, full-service and fast-food restaurants (2002b, 2006).

This study seizes an emerging opportunity to learn about the relationship between retail food environment and individual health outcome. Individual-level data from the latest wave of the California Health Interview Survey (CHIS) are mapped to county-level retail food index taken from a recent study about the food landscape in California. I examine whether the relative measure of food outlets affects individual body mass index after taking into account many individual characteristics and neighborhood sociodemographics.

METHODS

Data

Food environments

Using a dataset that included more than 88,000 food retailers in California, the California Center for Public Health Advocacy (CCPHA) analyzed data on fast-food restaurants, convenience stores, supermarkets, and produce vendors. The 1997 North America Industry Classification System (NIACS) codes were used to define types of food stores. The number of each type of retail food outlet for counties and cities with populations greater than 250,000 were calculated by ArcGIS version 9.0. Each retail food outlet is assigned to its appropriate census tract, and then summed across census tracts to determine the number of outlets by city or county. For the state of California as a whole and for each of these counties and cities, the Retail Food Environment Index (RFEI) is computed by dividing the sum of the number of fast-food restaurants and convenience stores by the sum of the number of supermarkets and produce vendors. CCPHA does not include gas stations with convenience stores in its construction of the index. This applies to all counties but some counties may harbor more of these types than others. A high RFEI means a less healthy food landscape as the region is more dominated by fast-food restaurants and convenience stores than supermarkets and produce vendors. More information on RFEI is available at CCPHA's website http://www.publichealthadvocacy.org/searchingforhealthyfood.html.

California Health Interview Survey

CHIS is a computer assisted telephone interview survey, representative of the state's non-institutionalized population living in households. It uses a two-stage, geographically stratified random-digit-dial sample design. CHIS covers a wide range of topics, including health status, health conditions, health-related behaviors, health insurance coverage, access to and use of health care services. Many CHIS questions are adapted from the National Health Interview Survey, other national and state surveys, and individual research projects that focus on population health. CHIS 2005 has 43,020 adults age 18 or older. I include 34,787 respondents living in 25 counties with population greater than 250,000 because RFEI is available only for these counties. More information on CHIS is available at http://www.chis.ucla.edu/.

Dependent Variable

Three individual-level dependent variables are examined. First I construct the body mass index (BMI), a continuous variable defined as weight in kilograms divided by the square of height in meters. Second, I derive a dichotomous variable for the overweight status

(= 0 if BMI < 25; = 1 otherwise). And third, another dichotomous variable is constructed for the obese status (= 0 if BMI < 30; = 1 otherwise). BMI was calculated from self-reported weight and height and is subject to the well-known biases of self-report data (Palta et al., 1982; Stunkard and Albaum, 1981; Kuczmarski et al., 2001).

Independent Variables

I map county-level RFEI to the individual-level data in CHIS. The key explanatory variable is the RFEI. The other independent variables include gender, race (*White*, Black, Hispanic, Asian , Pacific Islander, American Indian/Alaska Native, and other), age groups (*18-25*, 26-35, 36-45, 46-55, 56-65, over 65), marital status (*married or living with partner*, separated/divorced/widowed, other), employment (*employed,* unemployed), household income (*lowest*, 2nd, 3rd, highest income quartiles derived from self-reported total household annual income before tax), smoking status (*current smoker,* not a current smoker), alcohol consumption (any consumption of alcoholic beverage in the past 30 days), physical activity (*regular exercise,* no regular exercise) and urbanicity of residence (*rural*, urban).[6] In addition to these variables, I also extracted data from Census 2000 to control for tract-level population size, median household income, percent White population and percent Black population.

Statistical Methods

I employ multivariate linear regression for BMI and logistic regression for the likelihood of being overweight or obese. Below is a sketch of the model.

$$Y_{i,c} = \alpha_1 + F_c*\alpha_2 + N_{i,c}*\alpha_3 + I_{i,c}*\alpha_4 + \varepsilon_{i,c} \qquad (*)$$

where

[6] The reference group is in *Italic*.

$Y_{i,c}$ represents person i's BMI;

F_c represents county c's RFEI;

$N_{i,c}$ represents a vector of individual i' neighborhood sociodemographics;

$I_{i,c}$ represents a vector of individual i's characteristics;

$\varepsilon_{i,c}$ is the random error term, assumed to be normally distributed $N(0,\sigma^2)$;

$\alpha_{1,}$ α_2, α_3 and α_4 are a vector of the coefficients to be estimated.

Model (*) is run simultaneously and separately for women and men. After examining the effect of RFEI on individual BMI status, I conduct two statistical procedures to convert the estimated coefficients into more meaningful statistics. The first procedure is to estimate the adjusted prevalence of obesity for each county. After model (*) is estimated, I predict the obese likelihood for each individual. Using the California population characteristics for each county, I then estimate the obesity rate for a county using its current RFEI. In the second procedure, I assume that the statewide RFEI increased from its current level of 4.18 to 5.18, I then estimate how such a change in the retail food environment would affect the BMI status among women and men.

RESULTS

Table 6.1 presents descriptive statistics of the respondents in CHIS 2005. About half of women and two thirds of men are overweight, and one in every five adults is obese. The obesity epidemic is worse among those with lower education, lower income, and minorities except Asian. The prevalence of obesity among those without a high school diploma is twice higher than that among those with at least a college degree. Obesity rate is 23.7% among the lowest income quartile compared to 15.9% among the highest income quartile. Pacific Islanders suffer the highest obesity rate, 33.7%, in contrast to the lowest rate among Asian, only 7.0%. Lumping Pacific Islander and Asian into one race group, as it is often done in health research, would have obscured the dramatic difference in BMI status among these two groups.

There is large variation in the prevalence of obesity across California counties with the lowest rate in Marin County (11.5%) and the highest rate in Stanislaus County (31.5%). One of the several multi-year national objectives established by the U.S. Department of Health and Human Services' Healthy People 2010 initiative is to reduce the proportion of obese adults to 15 percent (DHHS, 2000). As of 2005, only 3 counties in California (Santa Cruz, San Francisco, and Marin) had obesity rate below the target objective, whereas the statewide obesity rate is 21.2%. Interestingly enough, the county-level RFEI also varies substantially. Figure 6.1 plots the unadjusted and adjusted obesity rates against the RFEI. There seems to have some correlation between the unadjusted obesity rates and the RFEI: Counties that are more dominated by fast food restaurants and convenience stores have higher unadjusted rates of obesity and vice versa.

After controlling for individual characteristics and neighborhood sociodemographics, RFEI is still significantly associated with individual BMI ($p<0.001$), overweight status ($p<0.001$), and obese status ($p<0.001$). Magnitude of the effect is non-trivial. Table 6.2 presents the results of three regression models estimating effects of RFEI on BMI gain, overweight status, and obese status. An increase of one unit of RFEI is associated with a gain of 0.18 units of BMI. Given the base overweight rate of 55.8%, the estimated odds ratio of 1.088 is translated into an increase of the overweight rate to 57.9% (increase by 2.1 percentage points). Similarly, the estimated odds ratio of 1.089 increased the base obesity rate from 21.0 to 22.4% (increase by 1.4 percentage points).

The large variation of obesity rates across counties depicted in Figure 6.1 can be attributable to the differential age distribution and sociodemographic characteristics of the population in each county. For instance, the population of Marin County (lowest obesity rate) has 79.9% of White and 12.0% Hispanic, compared to 55.7% and 40.0% of Stanislaus County (highest obesity rate). Solano County (obesity rate of 23.8%) has 17.3 % of its population 60 years or older while the corresponding statistic for Alameda County (obesity rate of 16.4%) is 14.7%. I therefore construct the adjusted obesity rates for each county and compare them to better understand the effect of retail food environment on the county-level prevalence of obesity. Figure 6.1 shows that, all else being equal, the prevalence of obesity is positively associated with the RFEI. The middle-point red dot in Figure 6.1 represents the adjusted obesity rate for Santa Clara County. It is 20.0% (95% C.I.: 19.9%, 20.1%) and statistically significant different from that of all other counties except for that of San Diego and Tulare Counties. Compared to the unadjusted obesity rates, the range of the adjusted rates is much narrower, varying from 17.0% (Santa Cruz County) to 21.8% (San Bernardino County). Or in other words, after controlling for all other characteristics in the regression model, the variation of RFEI (1.84 to 5.72) is associated with a variation of the adjusted obesity rates from 17.0% to 21.8% (compared to variation in the unadjusted rates from 11.5% to 31.5%).

The effect of retail food environment on BMI gain is larger for women. In Table 6.3, I present the simulated effect when the statewide average RFEI increases from 4.18 to 5.18. Women would gain on average 0.22 units of BMI compared to 0.12 units of BMI for men. The overweight proportion would increase from 45.6% to 47.7% for women (increase by 2.1 percentage points) and from 65.0% to 66.5% for men (increase by 1.5 percentage points).

The obese prevalence would increase from 18.7% to 20.2% for women (increase by 1.5 percentage points) and from 21.5% to 22.2% for men (increase by 0.7% percentage point).

Regression results for the other explanatory variables conform to findings of this literature. Men, age, minority (except Asian) are more likely to have higher BMI, be overweight or obese. Income, education, physical activity, smoking, and alcohol use are negatively associated with weight status. Among the neighborhood contextual factors, census tract median household income and percentage of the White population have independent and protective effect on individual BMI status.

DISCUSSION

The robust relationship found between RFEI and adult BMI status net of individual and neighborhood characteristics suggests that food environment can play a significant role in the obesity epidemic in California. My study contributes to the literature by analyzing individual obesity in relation to the relative availability of food stores rather than presence of a particular type of food outlet. Compared to the studies of neighborhood environments, which are subject to the self-selection bias, I do not believe that people sort themselves into a county because of its food environments. A county is large enough with many other important factors based on which people make their decision about residential place. I controlled for many individual and neighborhood characteristics that have been examined and attributed to affect the likelihood of obesity. That helps reduce the chance of having omitted variable bias. Though the dietary intake for each individual living a certain food environment is not observed in this study, an issue I discussed in Chapter Two regarding the importance of proper proxies for the "treatment", food outlets are certainly good proxies for food consumption. Retail food industry is locally demand driven. At the population level, if people did not buy food from the local stores in a manner that keeps the current relative position of retail food suppliers in place, the businesses would have exited the local market.

Magnitude of the effects of environmental factors such as food outlets may not be as small as their estimated odds ratios or coefficients appear. In contrast to the high-risk approach that seeks to protect susceptible individuals, the population approach attempts to affect the whole population (Rose, 2001). If the weight distribution curve shifts marginally to the favorable direction thanks to a positive change in the retail food environments, its effect can be very powerful. In fact, whether the environmental strategies can be cost-effective depends on two key conditions: the concentration of people around the center of the distribution curve and the average health-related status of the population. These two conditions are satisfied in case of the adult population's weight in California. There are much more people around the center of the BMI distribution curve whose mean is 26.5, already 1.65 excess units into the unhealthy weight range. Change in the food environments that affect average people's weight status can therefore bring about large-scale improvements.

There are, however, important limitations of this study and several questions remain to be explored. Given its cross-sectional analysis, a causal relationship cannot be claimed without a great deal of caution. RFEI measured at the county level do not reflect people's grocery shopping zones or away-from-home eating. A similar analysis of the relative food choices in the neighborhood environments would provide a valid test of their relationship with local residents' BMI status. Future research should also focus on plausible disparities in obesity-related health risks due to disproportional location of unhealthy food environments. Studies of this type have covered small geographical area and thus limited in their generalizability. The role of relative food availability in neighborhoods, possible interaction between locality, food prices and other environmental factors on obesity need better understanding.

RFEI is a compact measure of all sources of food stores in a location. It is an unadjusted measure, providing an image of the world without explaining the underlying factors that contribute to that stage of the world. The difference in the sociodemographic structure of the local population can be one of the causes for the substantial variation in the food landscape across communities. Future studies are warranted to investigate the underlying causes for their current status. Without understanding the way businesses come into being and compete to survive, regulation would be less likely to success.

Overall, this study supports the growing body of evidence that retail food environment plays an important role in individual dietary intakes and health outcomes. Among the approaches to the serious problem of obesity prevention, policy makers should consider weighting the option of improving supply of and access to more healthy food for the population in California.

Table 6.1: Descriptive Statistics of Respondents in CHIS 2005

Variable	CHIS 2003			
	Female (n=20,645)		Male (n=14,142)	
	Mean	Std. Dev.	Mean	Std. Dev.
Health-related Indicators				
Overweight	0.465	(0.50)	0.655	(0.48)
Obese	0.201	(0.40)	0.219	(0.41)
Any acohol use past 30 days	0.523	(0.50)	0.683	(0.47)
Heavy episodic drinking past 30 days	0.106	(0.31)	0.247	(0.43)
Current Smoker	0.114	(0.32)	0.187	(0.39)
Walking for fun	0.580	(0.49)	0.536	(0.50)
Sociodemographics				
Employed	0.591	(0.49)	0.771	(0.42)
Married	0.529	(0.50)	0.573	(0.49)
Never married	0.188	(0.39)	0.250	(0.43)
Separated/Divorced/Widowed	0.283	(0.45)	0.178	(0.38)
Age 18-25	0.144	(0.35)	0.158	(0.36)
Age 26-35	0.197	(0.40)	0.206	(0.40)
Age 36-45	0.209	(0.41)	0.226	(0.42)
Age 46-55	0.177	(0.38)	0.177	(0.38)
Age 56-65	0.123	(0.33)	0.117	(0.32)
Age over 65	0.151	(0.36)	0.117	(0.32)
No highschool diploma	0.161	(0.37)	0.170	(0.38)
High school diploma	0.266	(0.44)	0.250	(0.43)
Some college	0.257	(0.44)	0.230	(0.42)
College and higher	0.315	(0.46)	0.349	(0.48)
White	0.500	(0.50)	0.501	(0.50)
Black	0.067	(0.25)	0.056	(0.23)
Hispanic	0.252	(0.43)	0.273	(0.45)
Asian	0.138	(0.35)	0.127	(0.33)
Pacific islander	0.004	(0.07)	0.004	(0.06)
American Indian/Alaska Native	0.009	(0.10)	0.008	(0.09)
Other race	0.029	(0.17)	0.031	(0.17)
Lowest income quartile	0.303	(0.46)	0.233	(0.42)
2rd income quartile	0.247	(0.43)	0.249	(0.43)
3rd income quartile	0.239	(0.43)	0.245	(0.43)
Highest income quartile	0.211	(0.41)	0.274	(0.45)

Body Mass Index Status across Sociodemographic Groups

Sociodemographic groups	Overweight		Obese	
	Mean	Std. Dev.	Mean	Std. Dev.
No highschool diploma	0.678	(0.47)	0.284	(0.45)
High school diploma	0.573	(0.49)	0.230	(0.42)
Some college	0.578	(0.49)	0.233	(0.42)
College and higher	0.473	(0.50)	0.141	(0.35)
White	0.545	(0.50)	0.193	(0.39)
Black	0.667	(0.47)	0.330	(0.47)
Hispanic	0.662	(0.47)	0.278	(0.45)
Asian	0.326	(0.47)	0.070	(0.25)
Pacific Islander	0.742	(0.44)	0.337	(0.47)
American Indian/Alaska Native	0.616	(0.49)	0.290	(0.45)
Other race	0.637	(0.48)	0.225	(0.42)
Lowest income quartile	0.586	(0.49)	0.237	(0.43)
2rd income quartile	0.576	(0.49)	0.229	(0.42)
3rd income quartile	0.556	(0.50)	0.211	(0.41)
Highest income quartile	0.512	(0.50)	0.159	(0.37)

Note: Sample includes those in 25 counties with population ≥ 250,000.
Statistics are weighted.

Table 6.2: Estimated Effects of Retail Food Environment on BMI Status

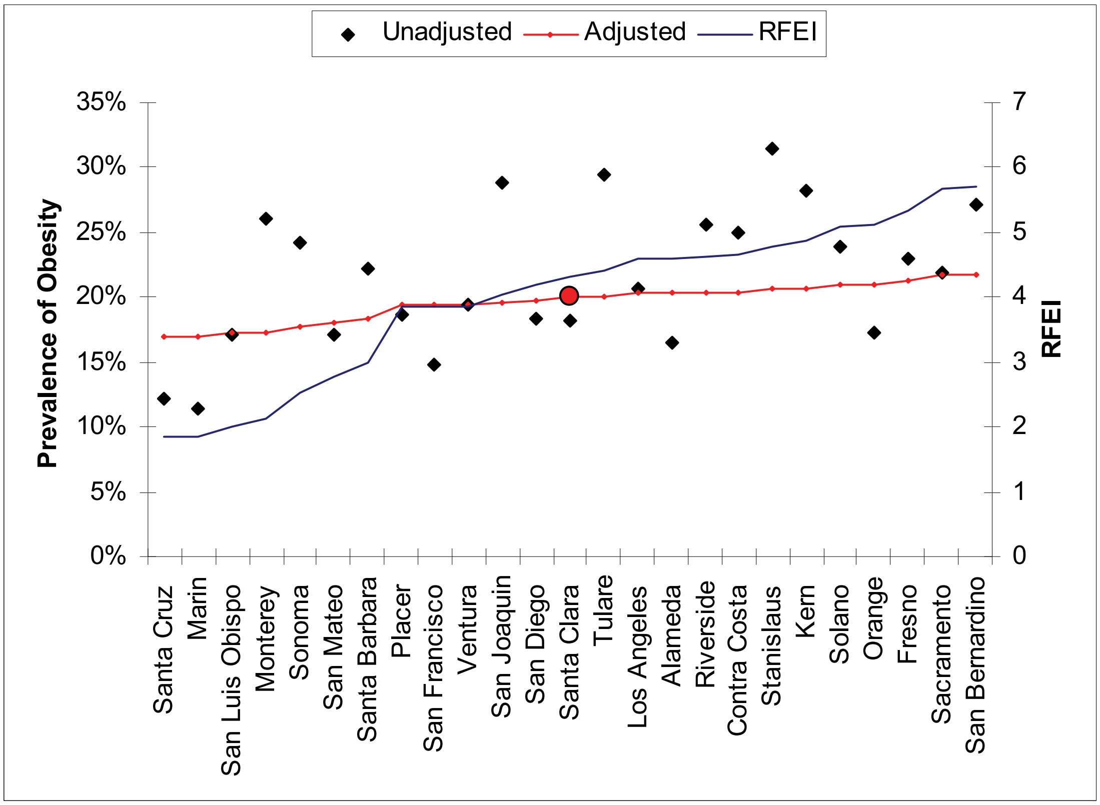
	BMI			Overweight			Obese		
Explanatory Variable	Coef.	Std. Err.		OR	Std. Err.		OR	Std. Err.	
RFEI	0.19	(0.03)	***	1.09	(0.01)	***	1.09	(0.02)	***
Male	1.40	(0.06)	***	2.42	(0.06)	***	1.21	(0.04)	***
Never married	-0.09	(0.09)		0.89	(0.03)	***	1.06	(0.05)	
Widowed/Divorced/Seperated	-0.05	(0.07)		0.94	(0.03)	*	1.03	(0.04)	
Age 26-35	1.78	(0.14)	***	2.03	(0.11)	***	1.90	(0.14)	***
Age 36-45	2.26	(0.13)	***	2.48	(0.14)	***	2.22	(0.16)	***
Age 46-55	2.92	(0.13)	***	3.12	(0.17)	***	2.72	(0.19)	***
Age 56-65	3.17	(0.14)	***	3.53	(0.20)	***	2.98	(0.22)	***
Age over 65	1.76	(0.14)	***	2.52	(0.15)	***	1.58	(0.12)	***
High school diploma	-0.55	(0.11)	***	0.85	(0.04)	***	0.94	(0.05)	
Some college	-0.67	(0.11)	***	0.85	(0.04)	***	0.90	(0.05)	*
College and higher	-1.63	(0.12)	***	0.57	(0.03)	***	0.58	(0.03)	***
Employed	0.13	(0.07)		1.13	(0.03)	***	1.01	(0.04)	
2rd income quartile	-0.15	(0.09)		1.03	(0.04)		0.98	(0.04)	
3rd income quartile	-0.11	(0.09)		1.04	(0.04)		1.00	(0.05)	
Highest income quartile	-0.53	(0.10)	***	0.92	(0.04)	*	0.82	(0.04)	***
Hispanic	0.81	(0.10)	***	1.44	(0.06)	***	1.12	(0.05)	*
Asian	-2.75	(0.10)	***	0.33	(0.01)	***	0.25	(0.02)	***
Pacific islander	1.76	(0.51)	***	1.91	(0.42)	**	1.80	(0.39)	**
Black	1.56	(0.14)	***	1.75	(0.10)	***	1.57	(0.10)	***
American Indian/Alaska Native	1.06	(0.29)	***	1.49	(0.18)	***	1.26	(0.16)	
Other race	0.33	(0.18)		1.28	(0.09)	***	1.08	(0.09)	
Current smoker	-0.70	(0.09)	***	0.79	(0.03)	***	0.79	(0.03)	***
Physical activity	-0.63	(0.06)	***	0.81	(0.02)	***	0.75	(0.02)	***
Any acohol use past 30 days	-0.59	(0.06)	***	0.91	(0.02)	***	0.78	(0.02)	***
Census tract population	0.00	(0.00)	*	1.00	(0.00)	**	1.00	(0.00)	
Tract median hshd income	-0.35	(0.09)	***	0.90	(0.03)	**	0.86	(0.04)	***
Tract % White population	-1.11	(0.15)	***	0.67	(0.04)	***	0.60	(0.05)	***
Tract % Black population	-0.14	(0.27)		0.78	(0.10)		0.67	(0.10)	**
Urban	-0.13	(0.10)		0.91	(0.04)	*	0.95	(0.05)	

Note:
The asterisk (*) indicates significance at 5% level; ** significance at the 1% level;
*** significance at 0.1% level.

Table 6.3: Simulated Effects of Retail Food Environment on BMI Status by Gender

		Current RFEI (4.18)		Simulated RFEI (5.18)		Difference
Mean BMI (95% C.I.)	Women	**25.7**	(25.7, 25.7)	**25.9**	(25.9, 26.0)	**0.22**
	Men	**27.1**	(27.1, 27.1)	**27.2**	(27.2, 27.2)	**0.12**
% Overweight (95% C.I.)	Women	**45.6%**	(45.5, 45.8)	**47.7%**	(47.5, 47.9)	**2.04%**
	Men	**65.0%**	(64.9, 65.1)	**66.5%**	(66.4, 66.7)	**1.53%**
% Obese (95% C.I.)	Women	**18.7%**	(18.6, 18.9)	**20.2%**	(20.1, 20.3)	**1.50%**
	Men	**21.5%**	(21.4, 21.6)	**22.2%**	(22.1, 22.3)	**0.69%**

Figure 6.1: Variation in RFEI, Unadjusted and Adjusted Obesity Rates across Counties in California



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