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Geographic Access and Demand in the Market for Alcohol*

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ABSTRACT: Policy in many regions restricts geographic access to alcohol by reducing the number of outlets where alcohol is available for purchase. In previous studies, imprecise measures of access and the lack of a theoretical framework have caused improper economic interpretations of how reducing access should affect consumer behavior. This paper makes several improvements in the study of geographic access to alcohol, employing new economic theory, new techniques for measuring access, and spatial econometric techniques. We find that although reducing access does reduce apparent per capita consumption of liquor, economic theory suggests that many alcohol-related problems are unlikely to be affected.

Keywords: Geographic Access; Liquor Demand

JEL Classification Codes: R22, R38, D12

1. INTRODUCTION

Although theoretical analyses of the interaction between consumer location and firm location have been common since the time of Sraffa (1926) and Hotelling (1929), little empirical research has been done to estimate the impact that transportation costs (i.e. geographic access) have on consumer demand. Additionally, almost all theoretical models assume that consumers face a transportation cost for *each unit purchased*. In many cases this simplifies the analysis because it is equivalent to analyzing a change in the price of a good. However, in most consumer markets these models are unrealistic.

In this paper we make several contributions to the spatial economic analysis of consumer demand. We analyze the market for retail sales of liquor (distilled spirits) in two contiguous "control"[1] states. First, making the assumption that consumers are likely to purchase from the closest liquor store to their residence, we create "market areas" for each of the 650 liquor stores in two U.S. States (North Carolina and Virginia). These market areas allow us to use U.S. Census data to find demographic characteristics of these consumers, and estimate the distance that consumers must travel to the nearest liquor outlet.

Second, we estimate demand functions using spatial regression techniques. These models allow for correction of spatial spillovers, as is the case when consumers purchase from a neighboring market area. Lastly, we do not interpret increasing travel cost as equivalent to an increase in price. Realizing that increasing travel costs do not affect the marginal costs, but are a fixed cost of access, we interpret the results in the context of a two-part tariff model.

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[1] In a control state the distribution of liquor is largely provided by government agencies. Most often this includes sales of liquor (and only liquor) in government-run stores.

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After reviewing the relevant literature in the next section, we describe the theoretical model in Section 3. In Section 4 we describe the data, and we discuss the estimation and results in Section 5. The implications of the results for alcohol control policy are given in Section 6.

2. BACKGROUND LITERATURE

2.1 Theoretical Models

Fetter (1924) was one of the earliest economists to model the impact of transportation costs on consumer behavior. Assuming that each unit purchased must be shipped at a freight rate that depends on distance, he describes how a firm's market area is determined based on the prices of its competitors and the freight rate. Hotelling's famous *Stability in Competition* (1929) and refinements by d'Aspremont, Gabszewicz, and Thisse (1979) furthered this research to consider the choice of firm location using Game Theory.

These models have been extended in many ways. For example, Prescott and Visscher (1977) and Salop (1979) use similar models to describe the extent of product differentiation and Spulber (1981) derives optimal nonlinear pricing functions for a spatial monopolist. However, all of these models either explicitly or implicitly assume that every unit purchased is subject to a separate transportation charge.

These per-unit transportation cost models make sense in some contexts, but do not properly model the choices faced by consumers in many others. Most consumer transactions involve a transportation cost that is relatively independent of the quantity of purchases made. In other words, consumers may incur costs of time, gas, and vehicle wear and tear, yet incur no marginal transportation cost for each item purchased. The cost of transportation is a hurdle that must be overcome that is then sunk, and thus irrelevant for the decision about quantity purchased.

There are very few discussions of lump-sum transportation costs in economic literature. Stahl (1982) uses a lump-sum transportation cost to explore the location of monopolistically competitive duopolists on a line, finding that lump-sum costs can provide some explanation for the agglomeration of firms. Burkey and Kurepa (2004) have solved pricing models with lump-sum transportation costs, comparing the results to those derived in per-unit models.

In a goods market such as that for liquor, two separate fees must be paid. First, a fixed fee of access that increases with distance must be overcome. Second, a per-unit price must be paid. A lump-sum travel cost is analogous to the fixed fee in a two-part tariff framework as discussed by Oi (1971) and Schmalensee (1981). In order to purchase a good, a consumer must pay a lump-sum fee. If the consumer pays the fee, then he can purchase any number of goods for a constant (marginal) price. We will return to these two-part tariff models in Section 3 and use them in the discussion of the empirical results in Section 5.

2.2 Empirical Models

In the arena of non-market goods, Hotelling (1947) is also credited with suggesting a method of estimating the value of national parks by the Travel Cost Method (TCM). The TCM is a method of estimating the willingness to pay for a nonmarket good by using the opportunity cost of time spent at a park as an estimate of the marginal cost the consumer pays, and the travel costs incurred (fixed fee) is used as a lower bound on the consumer's surplus for each visit. Collecting this data through surveys allows estimation of the market demand curve for a site.

However, the goal of the TCM is not to estimate how the transportation cost affects demand. The value of the transportation cost to the consumer is not estimated, but is normally assumed to be some fixed proportion of wages. [2]

Empirical models of transportation costs in product markets are rare. Davis (2006) includes customer locations in a model of spatial competition among movie theaters. Several studies measure the effects of geographic access to various medical services, including abortion (Kane and Staiger, 1996) and physician services (Newhouse et al., 1982). A very active research area focuses on the market for alcoholic beverages, however.

Beard, Gant, and Saba (1997) explicitly model a consumer's decision to drive across state lines in order to take advantage of price differences. They correctly realize the difference between a fixed transportation cost and the price paid. Using a model incorporating state prices, incomes, race, tourism, and sales, they estimate the amount of border-crossing behavior in northeastern alcohol markets. They find substantial amounts of border-crossing in the New York, Vermont, New Hampshire, and District of Columbia markets.

However, most research regarding geographic access to alcohol mistakenly equates the effects of restricting access to a price increase. While the effect of price increases on various types of drinkers is well understood (Manning, Blumberg, and Mouton, 1995; Cook and Tauchen, 1982), the effects of access are not. Most research on access finds that while apparent per capita consumption decreases when access costs increase, alcohol-related problems do not decrease; the authors are often puzzled at this result.

The findings appear to depend greatly on how access is defined, and whether the outcome measure correlates more to acute or chronic alcohol consumption. For example, one is certain to find that a neighborhood with many bars (high "access") will have high rates of drunk and disorderly conduct. However, one must use care to avoid confusing the factors that determine the location of drinking with those that may affect the frequency of consumption or volume consumed per occasion.

For example, Scribner, Cohen, and Farley (1998) found a positive relationship between alcohol availability and gonorrhea rates. Gyimah-Brempong (2001) found statistically significant relationships between access and a variety of crime measures. Markowitz (2000) and Gorman et al. (1998), however, both failed to find any relationship between measures of access and spousal abuse.

Gruenewald et al. (1996) find that although availability did not have a relationship with self-reported driving under the influence, there is a relationship with single vehicle, nighttime (SVN) crashes.[3] Focusing on vehicle fatalities of young men, Kelleher et al. (1996) found that availability played no role. Brown and Jewell (1996) found a small, statistically significant relationship between availability and cirrhosis mortality, but Xie, Mann, and Smart (2000) find no relationship. Tatlow, Clapp, and Hohman (2000) found that increased access had a positive relationship with alcohol-related hospital admissions. Lester (1995) found that measures of access to alcohol were related neither to suicide nor to homicide rates. Scribner et al. (1999), however, found that access was statistically significantly related to homicide rates in New Orleans. We will attempt to reconcile some of these apparent contradictions in the next section.

[2] See Cesario(1976) for a discussion of this issue.
[3] "SVN" crashes are often used as a proxy for alcohol-related crashes.

3. A THEORY OF DEMAND WITH ACCESS COSTS

In order to purchase a good, a consumer must incur a lump-sum travel cost (*T*). If the consumer pays the fee, then he can purchase any quantity for a constant price per unit (*p*). *T* will be a function of distance to a store, commuting patterns near stores, the number of stores, and the distribution of stores. The main difference between a two-part tariff model and the current framework is that the fixed fee is not collected by the firm, but has a similar effect of causing consumers to "disconnect" from the market when the fixed fee is sufficiently large.[4] We also include a taste parameter for alcohol that can be partially explained by demographic characteristics, *a*.

Let us construct a demand function for good *q*. Since the expenditure share for any one good is typically small, any income effects will be small.[5] Therefore, we will not dwell on the income effects in this analysis.

A consumer will choose to purchase the good if the consumer's surplus from the transaction is greater than the travel cost (given income *y*):

$$CS = \int_{P}^{\infty} q(a, y-T, p)dp > T \tag{1}$$

For a given $T=\overline{T}$, one could in principle find the minimum level of the taste parameter (a_m) and income (y_m) at which a consumer is indifferent between purchasing and disconnecting from the market and purchasing a substitute. The transportation cost only affects the choice of *whether* to purchase the good, while the price affects both *how much* is purchased and whether it is purchased. In both states considered in the empirical analysis, substitutes for retail liquor are readily available. For example, in North Carolina 25,943 businesses hold licenses to sell beer, wine, and/or mixed beverages. Only 77 of 739 zip codes contain no substitutes for retail liquor; 2.57 percent of the state's population live in these zip codes.

The preceding exposition uses several basic economic results to derive important new implications for the study of alcohol demand. For any given access cost, only those with sufficiently strong demand choose to purchase the good. As policies to reduce geographic access are strengthened, those with lower taste parameters drop out of the market first. In the absence of income effects, because the price of the good has not changed, consumption for those with sufficiently high demand is unaffected, but *per capita* consumption will fall as those with lower demand drop out of the market (and possibly purchase a substitute product).

When access costs increase, those consumers who continue to purchase the good may purchase or consume more on each trip in order to economize on the travel costs themselves. One can see this effect most easily in a dynamic framework within the well-known economic order quantity model.[6] In this model yearly demand (*D*) is normally assumed fixed, *C* is a per-item inventory cost, and *T* is a fixed ordering cost per transaction that is analogous to a travel cost. In Equation (2) below we see that the optimal *Q*uantity purchased per transaction is increasing in *T*, and in Equation (3) we see that the optimal *N*umber of transactions (trips) per year is decreasing in *T*.

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[4] That is, when it is larger than consumer's surplus.

[5] See Vives(1987).

[6] See Erlenkotter (1990) for some history and additional information on the EOQ model.

(2) $$Q^* = \sqrt{\frac{2TD}{C}}$$

(3) $$N^* = \sqrt{\frac{DC}{2T}}$$

Regardless, neither the static nor dynamic theories suggest that the highest demanders will moderate consumption as T increases.

These realizations help to explain the apparent inconsistency in the alcohol literature regarding the effect of access on outcomes associated with heavy, chronic drinking. Many of the studies finding relationships between access and crime measures may be finding that high concentrations of on-premise outlets are loci of criminal and drunken behavior, rather than the concentration of off-premise outlets causing increases in the rates of these behaviors. While apparent per capita consumption may decrease, this decrease is likely to reflect the truncation of the lower tail of the distribution rather than a change in the behavior of heavy consumers, who should be the target of policy reforms.

4. EMPIRICAL CONTEXT AND DATA

4.1 Context

With the above theory in mind, we now describe a data set that will be used to empirically describe some of the implications of the model. Sadly, a direct test of the model is not possible using available data. To directly verify the predictions that those with lower demand for alcohol drop out of the market while those with higher demand are unaffected would require a micro data set on alcohol consumption that contains a meaningful measure of geographic access. At this point, no such data set exists.

Because the basic elements of the theory are well-understood, we will instead use the available data to perform two tasks. First, we will estimate parameters for a demand function that can be interpreted using the theory presented in Section 3. Second, we will interpret these estimates in a detailed manner with the aid of additional theoretical results.

We construct our data set using retail liquor outlets in North Carolina and Virginia during 2003. We use these contiguous states because in these states, only liquor is sold in these outlets.[7] This creates a situation where a special stop (if not a special trip) must be made in order to purchase liquor in these states. Additionally, advertising, pricing, and selection are all regulated and fairly homogenous both within and between these states. Table 1 provides important statistics on state characteristics for comparison. Table 2 provides a comparison of the pricing formulas in each state.

We see that these two states are almost identical in most respects, except that while North Carolina has a larger area, it appears to have much higher access to alcohol. Two common measures of access are shown, Stores/Capita and Stores/Square Mile. Using these simple

[7] A small amount of wine is sold at liquor stores in each state. In North Carolina, it is only for special orders for products not imported into the state by a wholesaler. In Virginia, products produced by Virginia vintners are sold in ABC stores. Additionally, a small variety of "mixers" are sold at stores in both states. However, both wine and mixer sales account for much less than 1 percent of total revenue.

TABLE 1. Descriptive Statistics for Virginia and North Carolina, 2003

	Virginia	North Carolina
Population	7,078,515	8,049,313
Area (Square Mi.)	40,815	52,712
Annual Sales Retail	$353,289,410	$396,306,047
Number of Stores	269	381
Retail Sales per Store	$1,313,344	$1,040,173
Stores/100,000 Population	3.80	4.73
Stores/1000 Square Miles	6.59	7.23
Sales Per Capita	$49.91	$49.23

TABLE 2. Breakdown of $3 (distiller's price) bottles of liquor in each state

	Virginia	North Carolina
Distiller's price	$3.00	$3.00
Federal tax	2.24	2.24
Markup	2.50	2.38
State excise tax	1.60	2.02
Warehouse charge	0.11	0.14
Total:	$9.45	$9.75

one may wonder why the per capita sales are almost identical despite better access in North Carolina. How access is measured should be carefully considered.

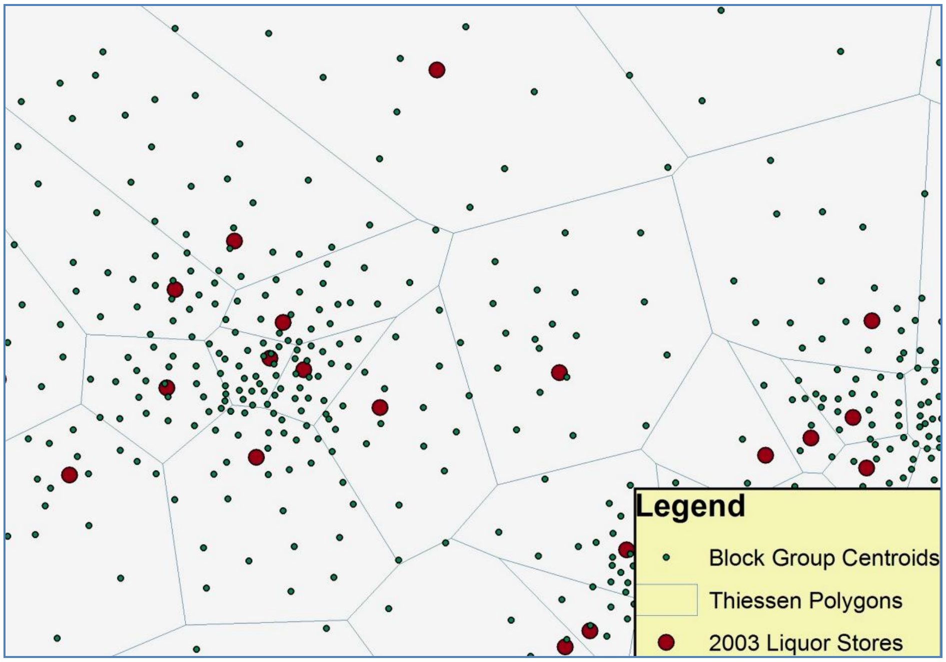
4.2 Measuring Access

Consider two square counties that have five liquor stores each. County A has one store located in each corner, and one in the center of the county. County B's five stores are located on top of one another in the center of the county. Previous measures of access would treat these two counties in the same way. However, because access should be a proxy for a transaction cost associated with purchasing alcohol, this is unacceptable.

We use the individual outlet as the level of observation for this study. The locations and sales are determined and the characteristics of those living nearest the stores are determined from census data at the block group level (groups of approximately 1,500 residents). Characteristics including income, racial characteristics, tourism, and unemployment rates are used as control variables.

In order to match consumers to stores, we create market areas with *Thiessen Polygons* (Figure 1) around each outlet. These polygons simply define all areas that are closer to a

FIGURE 1: Thiessen Polygons for Liquor Stores



particular store than any other store, where the liquor outlet is represented by a point roughly in the center. All census block groups whose center (centroid) is located in a given outlet's polygon will be matched to that store for analysis.

This method makes the rather strong assumption that consumers patronize the store closest to where they live. We attempt to correct for violations in this assumption using econometric techniques. The measure of access we use here is defined as the weighted average of consumer distance to the closest store. This distance is computed as follows:

$$\bar{T} = \frac{\sum_n P_n D_n}{\sum_n P_n} \quad (4)$$

where P is the number of consumers in block group n, and D is the distance from the center of the block group to the closest store. The summation is over the number of block groups closest to a particular store. There are 10,001 block groups and 650 stores in this study, for an average of 15.4 block groups associated with each store. The natural log of the distance is used, so that its parameter estimate represents an elasticity.

4.3 Other Data

Data on sales and location for each store in North Carolina are based on an original data set collected for this study in cooperation with the North Carolina ABC Commission for the year 2003. The data on sales and location for each store in Virginia came from the Virginia ABC Commission. Data on religious affiliation was taken from *Religious Congregations and Membership in the United States 2000*.[8] The source for all other socioeconomic data is the 2000 decennial U.S. Census. All of the socioeconomic variables were measured by block group, and weighted averages over the consumers of a given store were computed for use in the regressions.

[8] Jones et al. (2002)

Sales is the dollar amount[9] sold per store retail, not including the sales these stores make to restaurants or bars. This figure is divided by the number of potential consumers patronizing a store, and the natural logarithm of this per capita figure is used in regressions. The number of potential consumers was defined as follows: first, the number of people 18 and over was computed. While the *legal* drinking age is 21 in the U.S., failing to include those 18 to 20 as demanders would ignore the importance of this segment of the market. In 1995, approximately 10 million Americans under the age of 21 reported having at least one alcoholic drink in the previous month (NIDA, 1995). Although many people under the age of 18 also drink alcohol, 18 years appears to be an empirically valid cutoff point. The percentages of 16-17 year olds who use alcohol or binge drink are roughly half that of the 18-20 year old and 21 and over rates (NIDA, 1995).

From this number of potential consumers, institutionalized persons and military personnel were removed. Institutionalized persons undoubtedly face large obstacles when attempting to obtain liquor; thus removing nursing home and prison populations is in order. Any consumption by these persons will increase the apparent consumption of those living near such an institution, but such effects will surely be very small. Military personnel were removed because liquor is available on base at much lower prices (paying little to none of the taxes in Table 2), and is not sold through the state control systems.

Religion is measured in two ways. First, the percentage of county residents who are affiliated with the Southern Baptist Convention is used. The Southern Baptists represent a large portion (31 percent) of the religious population in Virginia and North Carolina, and as much as 60 percent of the general population in some areas. Southern Baptists were also chosen because of their historical, decidedly anti-liquor position (Rosenberg, 1989). Since these data were available only at the county level, the percentage of residents who are "adherents" [10] of a Southern Baptist church in the county in which a liquor store is located is used. Additionally, the percentage of residents who are adherents of any other religion (not including Southern Baptists) was also used as a control.

Race is controlled for using the percentage of inhabitants of a market area that are of a race other than white, non-Hispanic. Typically, nonwhites drink less than whites do. Whites have a usage rate of 56 percent, compared with 45 percent and 41 percent for Hispanics and Blacks, respectively (NIDA, 1995). Thus, the expected sign of the coefficient on this variable is negative.

The natural log of the weighted average per capita **income** is used, calculated in a fashion similar to Equation (2). This elasticity is expected to be positive, since an increase in income is likely to increase both the quality and quantity of liquor purchased. Because prices are fixed at every store but higher-income patrons may select more expensive brands, the income variable controls for variation in both demand and quality selection effects.

[9] Ideally one would use the *quantity* of alcohol sold, however, this data is not recorded for most individual stores in North Carolina. Sales will tend to overestimate quantity in affluent areas, because through product selection the average price per unit is higher in these areas. The income variable will control for this "quality-selection effect".

[10] Adherents include full members, their children, and regular attendees of a church, synagogue, or mosque.

A dummy variable is used to capture any effects that **Virginia**'s liquor stores may have on sales. This may capture such factors as the 3 percent price difference between North Carolina and Virginia, minor differences in selection, or other factors.[11]

Two variables were included to control for **substitutes**. As a possible substitute for retail liquor to drink at home, the availability of Mixed Beverages[12] was included, measured as the number of outlets per 10,000 people in the market area. This variable was generated using GIS tools and liquor license data. It should indicate if liquor by the drink substitutes, complements, or is unrelated with respect to availability and consumption of liquor from retail stores. Additionally, the percentage of those in the labor force that **commute** more than 15 minutes to work was included as a control for "spatial substitutability". If a large share of residents commute a long distance, then they are more likely to come in contact with a liquor store that is not the one closest to their home.

Border Effect Dummies: Stores that are located in North Carolina or Virginia in a market area bordering another state have a dummy variable indicating the state that they border. Virginia borders Maryland; Washington, D.C.; West Virginia; Kentucky; and Tennessee. North Carolina borders South Carolina, Georgia, and Tennessee. These variables are included to account for any border-crossing that may occur due to price differences. While it is not possible to make categorical statements comparing prices in different states due to differences in taxes, competition, and other factors, Maryland, D.C., West Virginia, South Carolina, and Kentucky have generally lower prices than do North Carolina and Virginia, while prices in Tennessee and Georgia are generally higher.

Large numbers of **tourists** or business travelers tend increase the apparent consumption of those living in an area. Census data that measures the percentage of the labor force employed in entertainment or recreation fields is used as an indicator of the amount of tourism in an area relative to the size of the population.

The **unemployment rate** for each group of consumers is calculated from the census data. The number of those unemployed is recorded for each block group. This number is divided by the total number of persons minus those identified as labor-force nonparticpants. This variable is expected to have a positive relationship with alcohol sales for two reasons. First, unemployed people tend to have more time available to consume alcohol. Additionally, they may be more likely to abuse alcohol. Due to tax rates, however, liquor is the most expensive delivery method for alcohol use in most states (see e.g. Cook and Moore, 1994). Descriptive statistics appear in Table 3. A correlation matrix for the independent variables in Appendix Table A1 shows that the highest correlation between explanatory variables is 0.599, so multicollinearity is not a likely problem.[13]

[11] For example, only Virginia allows the use of "cents off" coupons.
[12] A drink served in a bar or restaurant containing liquor.
[13] E.g. Kennedy(1998) suggests that 0.8 or 0.9 in absolute value is a "high value" (p. 187)

TABLE 3. Descriptive Statistics

Variable	Mean	Units	St. Dev.
Per Capita Sales	73.84	Dollars	48.81
Distance to Closest Store	3.43	Miles	2.02
Per Capita Income	21,079	Dollars	7,383
Religion (% South. Baptist)	13.58	Percent	7.88
Other Religious Adherents	29.38	Percent	7.85
Mixed Beverage Outlets	6.14	Rate/10,000 pop	8.06
Over 15 Mile Commute	69.53	% of Labor Force	9.73
% Unemployment	5.13	Percent	2.87
% Nonwhite	29.05	Percent	19.61
% Ent/Rec Empl.	6.64	Percent	2.85

5. EMPIRICAL ESTIMATION AND RESULTS

We begin with the basic log-log OLS equation:

(5) $$\ln Q_i = a \ln T_i + b \ln Y_i + cD_i + \varepsilon_i$$

where Q_i is the dollar amount of apparent per capita consumption, T_i is a measure of access, Y_i is a measure of income, and D_i are other demographic and explanatory variables. The one variable that is conspicuous in its absence in Equation (5) is price. Price is not included as a variable because within these two states the price of liquor is determined by a formula (see Table 2). The resulting prices are very similar in the two states, the difference being somewhere on order of 3 percent. For example, the most popular seller in Virginia is Jack Daniel's 7 Black. For a 750ml bottle, the price is $23.50 in Virginia and $24.50 in North Carolina. However, for a 1.75L bottle, the price in North Carolina is slightly lower ($46.95 vs. $47.95). The Virginia dummy variable should capture any effects from these small differences.

These regressions will be tested for the presence of spatial structure. Because these data are explicitly spatially related, omitting the testing and required corrections can cause omitted variable bias and/or inefficiency. There is a potential for spatial spillover effects as customers of one area purchase in neighboring market areas.

5.1 Spatial Econometric Models: Lag vs. Error

Because neighboring areas are likely to be related through unobserved spatial dependence or spatial heterogeneity, the first task is to define the manner in which areas are considered neighbors. This can be done in several ways, including areas that share a common boundary or areas that are within, say, 15 miles of one another. In this paper we define areas as neighbors using *queen contiguity*; that is, areas are considered neighbors if they share a common boundary or meet at a corner. Then, a contiguity (i.e. spatial weights) matrix is constructed which mathematically represents these neighbor relationships. The two basic classes of spatial models are spatial *error* and spatial *lag* models.

A spatial ***lag*** model is appropriate when activity in one location both affects, and is affected by, activity in neighboring locations, or when there is spatial contagion of a disease or a trend over space and through time. Spatial ***error*** models are often employed when data on important variables involving the spatial structure of an activity are unobserved. Alternatively, one can interpret these models as incorporating the fact that unobserved influences are correlated across space. In these cases, the error terms in a regression will tend to be spatially correlated. Econometrically, the spatial lag model is estimated via a "spatial autoregressive model" (Anselin, 1988).

(6) $$y = \rho Wy + X\beta + \varepsilon$$

Simply stated, this formula tests the hypothesis that per capita consumption (*y*) is a both a function of explanatory variables ($X\beta$) as well as a function of the per capita consumption of neighboring areas (ρWy). Here, ρ is constrained to be less than one, and describes the "strength" of the spatial dependence.

In a similar fashion, the spatial error model assumes a spatial correlation among the error terms:

(7) $$y = X\beta + u, \quad u = \lambda Wu + \varepsilon, \quad \text{where } \varepsilon \sim \text{i.i.d.}$$

The failure to estimate a spatial lag model (when called for) will lead to inconsistent and biased estimates. However, in the case of a spatial error model OLS estimates are unbiased, but inefficient. There are several other flavors of spatial econometric models, most notably the spatial Durbin model because it nests the spatial error and lag models as special cases. It takes the form

(8) $$y = \rho Wy + X\beta + WX\theta + \varepsilon$$

If θ=0, then (8) degenerates into the spatial lag model, and if θ= $-\rho\beta$, then (8) simplifies into the spatial error model (because λ=ρ in this case).

A spatial specification search can take one of three paths. If the spatial structure is known a priori, then this should guide the modeling decision. However, if there is uncertainty about the spatial structure, traditionally a "specific-to-general" approach has been used. One starts by running an OLS model, and then one can perform Lagrange Multiplier tests to determine the form of the spatial dependence. However, LeSage and Pace (2009)[14] advocate the "general-to-specific" approach, which entails running the spatial Durbin model first, and testing for the restrictions mentioned above in order to see if either the spatial error or lag models are adequate. We will demonstrate both approaches in the next section.

[14] See Elhorst (2010) for an excellent review and discussion of LeSage and Pace's book.

TABLE 4. Model Estimates (OLS)

Variables	Coefficient	Std. error	*t*	*p* value
(Intercept)	0.7408	1.0904	0.679	0.497
log(Ave. Dist.)	-0.1212	0.0427	-2.84	0.005
% nonwhite	0.0019	0.0015	1.26	0.208
log(PCI)	0.4327	0.1065	4.062	<.001
% Unemployment	-0.0112	0.0099	-1.138	0.256
% Ent/Rec Employment	0.0449	0.0078	5.733	<.001
DC	-0.4145	0.1955	-2.12	0.034
GA	0.3947	0.3315	1.191	0.234
KY	-0.2555	0.1994	-1.281	0.201
MD	-0.0866	0.1473	-0.588	0.557
SC	-0.1531	0.0936	-1.636	0.102
TN	-0.1164	0.1491	-0.781	0.435
WV	-0.1576	0.1205	-1.307	0.192
VA	-0.0797	0.0415	-1.918	0.056
% Southern Baptist	-0.0003	0.0028	-0.118	0.906
Other Adherents	-0.0077	0.0027	-2.844	0.005
Mixed Bev. Availability	0.0123	0.0088	1.404	0.161
Long Commuters	-0.0110	0.0023	-4.742	<.001
R^2=0.2953 N=650				

5.2 OLS Results and Specification Tests

The results of OLS estimation are shown in Table 4.[15] Using these results as a starting point, we calculate Lagrange Multiplier (LM) tests for the lag and error models described above.[16] Because each LM test can result in a false positive for the other type of model, a robust form of each test is also used. The LM Tests (Table 5) for both models are statistically significant; however, only the Robust LM statistic for the spatial lag model is significant. Thus, the specific-to-general approach points toward the spatial lag model as the correct specification, shown in Table 6. Tests for residual spatial error correlation and heteroskedasticity indicate no problems, and so we can be confident in these results.

[15] All data analysis was performed using the R language system (R Development Core Team, 2009) including the **spdep** spatial analysis add-in (Bivand et al., 2010).

[16] See Anselin(1988) and Anselin, Bera, Florax, Yoon (1996) for details about these tests.

TABLE 5. Lagrange Multiplier Diagnostics for Spatial Dependence

Variables	LM Coefficient	*p* value
LM Error	5.380	0.020
Robust LM Error	0.556	0.456
LM Lag	8.672	0.003
Robust LM Lag	3.848	0.050

TABLE 6. Model Estimates (Spatial Lag)

Variables	Coefficient	Std. error	*z*	*p* value
(Intercept)	0.4052	1.0765	0.376	0.707
log(Ave Dist.)	-0.1214	0.0418	-2.907	0.004
% nonwhite	0.0018	0.0015	1.228	0.220
log(PCI)	0.4002	0.1045	3.829	<0.001
% Unemployment	-0.0109	0.0097	-1.133	0.257
% Ent/Rec Employment	0.0396	0.0078	5.090	<0.001
DC	-0.3895	0.1914	-2.036	0.042
GA	0.3920	0.3242	1.209	0.227
KY	-0.3051	0.1953	-1.562	0.118
MD	-0.0793	0.1441	-0.550	0.582
SC	-0.1317	0.0917	-1.437	0.151
TN	-0.1007	0.1459	-0.691	0.490
WV	-0.1652	0.1179	-1.401	0.161
VA	-0.0717	0.0408	-1.756	0.079
% Southern Baptist	0.0004	0.0028	0.156	0.876
Other Adherents	-0.0074	0.0027	-2.752	0.006
Mixed Bev. Availability	0.0132	0.0086	1.533	0.125
Long Commuters	-0.0107	0.0023	-4.740	<.001

Rho: 0.15727 LR test value: 7.9139 *p*-value: 0.0049

LM test for residual autocorrelation: test value: 0.8668 *p*-value: 0.3519

Spatial Studentized Breusch-Pagan Test[a]: BP = 17.0072, df = 17, p-value = 0.4539

Note: [a] (Anselin, 1988; Bivand, 2010)

TABLE 7: LR Tests for Restricting Durbin to Lag and Error Models (17 *df*)

Model	log likelihood	LR Stat	Significance
Durbin	-384.873		
Lag	-401.195	32.644	p=0.013
Error	-402.414	35.082	p=0.006

TABLE 8. Model Estimates (Spatial Durbin)

Variables	Coefficient	Std. error	*z*	*p* value
(Intercept)	-0.9691	2.2593	-0.4289	0.6680
log (Ave. Dist.)	-0.1654	0.0427	-3.8709	0.0001
% non-white	0.0006	0.0016	0.3470	0.7286
log(PCI)	0.4006	0.1089	3.6796	0.0002
% Unemployment	-0.0079	0.0095	-0.8279	0.4077
% Ent/Rec Empl	0.0341	0.0086	3.9662	0.0001
DC	-0.4171	0.1904	-2.1911	0.0284
GA	0.0388	0.3518	0.1103	0.9121
KY	-0.4913	0.2220	-2.2130	0.0269
MD	0.0426	0.1445	0.2946	0.7683
SC	-0.0235	0.1371	-0.1713	0.8640
TN	-0.1045	0.1565	-0.6678	0.5042
WV	-0.0566	0.1219	-0.4646	0.6422
VA	-0.0850	0.1893	-0.4487	0.6536
% Southern Baptist	0.0084	0.0037	2.2749	0.0229
Other Adherents	-0.0099	0.0031	-3.2310	0.0012
Mixed Beverage Availability	0.0179	0.0090	1.9996	0.0455
Long Commuters	-0.0084	0.0023	-3.6085	0.0003
lag.log(Ave. Dist.)	0.0613	0.0869	0.7053	0.4806
lag.% nonwhite	0.0021	0.0032	0.6495	0.5160
lag.log(PCI)	0.1270	0.2250	0.5642	0.5726
lag.% Unemployment	-0.0036	0.0232	-0.1536	0.8779
lag.% Ent/Rec Empl.	0.0409	0.0163	2.5121	0.0120
lag.DC	-0.0051	0.4544	-0.0112	0.9911
lag.GA	-0.1590	0.7362	-0.2160	0.8290
lag.KY	1.2336	0.5401	2.2840	0.0224
lag.MD	0.3956	0.3620	1.0926	0.2746
lag.SC	-0.2396	0.2140	-1.1195	0.2629
lag.TN	-0.2576	0.3109	-0.8284	0.4074
lag.WV	0.1912	0.2946	0.6489	0.5164
lag.VA	-0.0510	0.1985	-0.2570	0.7972
lag.% Southern Baptist	-0.0113	0.0055	-2.0599	0.0394
lag.Other Adherents	0.0067	0.0050	1.3289	0.1839
lag.Mixed Bev Avail.	-0.0446	0.0187	-2.3863	0.0170
lag.Long Commuters	-0.0030	0.0050	-0.5987	0.5494

Rho: 0.11715, LR test value: 3.5346, p-value: 0.0601
LM test for residual autocorrelation test value: 3.421, p-value: 0.0644
Spatial Studentized Breusch-Pagan Test BP = 31.4742, df = 34, p-value = 0.592

TABLE 9. Direct and Indirect Effects of Variables of Interest

Variable	Direct	Indirect	Total
log(Ave. Dist)	-0.165	0.047	-0.118
log(PCI)	0.404	0.193	0.598
% Ent/Rec. Empl.	0.035	0.050	0.085
DC	-0.418	-0.060	-0.478
Baptists	0.008	-0.011	-0.003
Other Adherents	-0.010	0.006	-0.004
Mixed Beverage	0.017	-0.047	-0.030
Long Commuters	-0.008	-0.004	-0.013

However, Elhorst (2010) suggests that if either LM test is positive, the next step should be to estimate the spatial Durbin model. Then, likelihood ratio (LR) tests can be used to test restrictions of the model to determine if the spatial lag or error models are adequate. As previously mentioned, LeSage and Pace (2009) recommend starting the specification search with the spatial Durbin model in any case. The log likelihood LR tests for restricting the model to the spatial lag or error models are shown in Table 7 and estimates for the spatial Durbin model are shown in Table 8. Because these LR tests are highly significant, the general-to-specific method clearly indicates that the spatial Durbin model is the most appropriate. Note that in the spatial Durbin model each coefficient has two estimates, one for the direct effect, and one for the indirect (lagged) effect.

In order to easily discuss marginal effects of coefficients in models such as the lag or Durbin models, which contain a spatially lagged dependent variable, it is necessary to use LeSage and Pace's (2009) suggested method for calculating the average direct and indirect (feedback) effects for each of the variables of interest (Table 9). Unless otherwise noted, we discuss the Total Effect of these impacts.

5.3 Discussion of Results

The income elasticity of 0.598 is a little higher than estimates found in previous studies because of the dual role of the income variable here controlling for quantity as well as quality, and confirming that liquor is a normal good.[17] The coefficient on the percentage of workers in the entertainment and recreation industry is statistically significant, positive, and large for both the own and lagged values. The coefficient implies an 8.5 percent increase in per capita sales for each 1 percentage point increase in the labor force employed in entertainment/recreation fields. The large size on the entertainment and recreation variable is understandable, since a change of one percentage point in employment in these fields represents a large change in tourism given that the median in the data is 5.9 percent.

The own border dummy for Washington, D.C., is statistically significant, consistent with the fact that it has much lower prices than Virginia. Per capita sales are roughly 42 percent lower in counties bordering these regions, possibly indicating border-crossing sales and

[17] For example Cook and Tauchen's (1982) estimate for income elasticity is 0.43.

commuter effects. The Virginia dummy variable is not significant in the Durbin model, indicating no difference between sales in the two states, *ceteris paribus*.

Interestingly, the percentage of the population that is Southern Baptist is positive for the direct effect, but negative for the lagged impact. The measure for other religious affiliation (Adherents) is negative and significant for the direct effect, but the lagged value is not statistically significant.

Availability of mixed beverages in restaurants has a positive direct effect, indicating complementarities between on- and off-premise purchases of liquor, but the negative indirect impact moderates this so that the total effect suggests substitutability. The impact of long commuters is negative, as expected.

5.4 The Interpretation of Access

As expected, the coefficient on the access measure is negative and significant in all three models estimated, and the marginal effects imply a marginal effect of around -0.12. This can be interpreted as an elasticity: for each 1 percent increase in distance, per capita purchases drop by approximately 0.12 percent. Thus, we can see that this relationship is very inelastic. As discussed in the theory in Section 3, this elasticity of -0.12 stands in stark contrast to consensus estimates of the price elasticity of demand for liquor, -1.5 (NIAAA, 2001), reinforcing the theoretical differences we outlined.

As we observe the average travel distance for a store's market area increase, one would (ceteris paribus) expect *total* sales to increase as more customers are included in the market area. However, one would expect a smaller fraction of these customers to connect because of higher travel costs. Thus, what we have is a measure of an "apparent"[18] travel cost elasticity of demand. We can write this elasticity as follows:

(9) $$\varepsilon_{tc} = \frac{\partial(\frac{P*Q}{\tilde{N}})}{\partial T} * \frac{T}{\frac{P*Q}{\tilde{N}}}$$

where $\tilde{N}$ is the total population in a market area. Given that P is fixed by the same formula at all stores, we can write $\partial(P*Q/\tilde{N}) = P*\partial(Q/\tilde{N})$, and the price will cancel out of the elasticity. The elasticity now involves only quantity, not dollar value of sales. In addition, if we assume that the quantity sold is a linear function of $\tilde{N}$ (ceteris paribus), then we can also bring out the $1/\tilde{N}$ from the derivative, and it, too, cancels out. This gives:

(10) $$\varepsilon_{tc} = \frac{\partial Q}{\partial T} * \frac{T}{Q}$$

Recall that in Section 3 it was argued that consumers will respond to increases in travel costs just as they would to an increase in a fixed fee in a two part tariff. Schmalensee (1981) derives some useful relationships describing how consumers will behave in such a model. Let $\hat{q}$ be the quantity demanded by a *marginal* consumer, and let subscripts denote partial derivatives. In a model assuming that income effects are zero:

(11) $$N_P = \hat{q}N_T = Q_T$$

[18] "Apparent," because this elasticity does not describe how individuals respond, but rather how the aggregate sales respond.

Here N reflects the number of consumers who actually connect to the market. Equation (8) states that a price increase of ΔP has the same disconnection effect as a $\hat{q}\Delta T$ increase in travel costs. The last equality simply states that the change in the quantity sold in the market as transportation costs increase must equal $\hat{q} * N_T$. In this context, T must be in dollar units rather than miles. As a very rough estimate, let us assume that the IRS figure of 36 cents per mile in 2003 is a rough approximation of marginal (rather than average) travel costs, including the consumer's time.

Converting miles into a travel cost in dollar units will not change the point estimate of the elasticity, because this will change both the measure of T and the magnitude of ∂T by identical amounts. However, in order to isolate Q_T from the elasticity, we should multiply by the average value of Q/T from the data. The average Q (in bottles) per store was around 83,000 and average travel cost was \$2.46, measuring distance as the crow flies. If we inflate this cost by 30 percent in order to account for actual road networks in these two states (Burkey, 2010) this gives a better estimate of \$3.20 per trip. This gives a measure of -3,113 for Q_T, which should also equal N_P for the average store. The major problem with the calculation of Q_T above is that the \$3.20 figure is *per trip*, using yearly figures. Since more than one trip per year is probably taken by those who connect, 3,113 is certainly an upper bound on $|Q_T|$. In addition, \$0.36 per mile is probably a fairly low estimate of marginal cost per mile, reinforcing the likelihood that $|Q_T|$ is less than calculated.

Even so, approximately –3,000 is not a wholly unreasonable value for Q_T and N_P. Suppose that this value would hold for a \$1 change in travel cost or price. Given that the average number of potential customers per store is around 15,000, N_P would indicate that increasing the price of liquor \$1 (approximately 10 percent) would cause 3,000 marginal customers to disconnect. While this does seem drastic, it is not out of line with Cook and Tauchen's (1982) price elasticity estimate of -1.8 and consensus estimates of -1.5. The above price increase would cause a decrease in total quantity demanded of 15-18 percent, which would include a sizeable percentage of consumers (the low demanders) dropping out of the market and purchasing a substitute.

Q_T would tell us that the average number of bottles sold per store (83,000) will drop by about 3,000 if travel costs are increased by \$1. This number also seems to be within the bounds of reasonability. If we had data on $\hat{q}$, the quantity consumed by a marginal consumer per year, we could estimate $N_T = \frac{3000}{\hat{q}}$. Supposing that $\hat{q}$ is 1 or 2 bottles per year would lead us to conclude that N_T is between 1,500 and 3,000 for an average store.

6. CONCLUSION

While it is still argued by many non-economists that consumers will react to increases in travel costs as an increase in price, in this paper we show that the travel cost elasticity of retail liquor purchases is substantially smaller than consensus estimates for the price elasticity of demand for liquor, and is theoretically a very different concept. Increases in a fixed fee should have no marginal effect on a consumer's purchases. Instead, consumers with sufficiently low surplus will disconnect from the market entirely and purchase a substitute.

With an estimated elasticity of -0.12, consumers are extremely inelastic in their response to accessibility to retail liquor, but are elastic with respect to price (ε_p= -1.5). The two states examined in this study are currently considering privatizing liquor sales[19], but are concerned that privatization would lead to higher numbers of stores, and therefore higher consumption. The preceding analysis suggests that policymakers have a more effective tool in restraining consumption by keeping prices high, rather than keeping accessibility low. Thus, privatization could succeed by focusing on taxes to keep prices high, and leave the number and location of facilities to the market process.

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[19] See Robertson (2010) and Hinkle (2010), for example.

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Appendix Table A1. Correlation Matrix

	%nonwhite	commute	%unemp	%Ent/Rec Empl.	PCI	%Baptist	%Adherents	Mixed Bev.
%nonwhite		0.004	0.599	-0.036	-0.369	-0.078	-0.202	-0.023
commute	0.004		-0.316	-0.432	0.186	-0.112	-0.110	-0.287
%unemp	0.599	-0.316		0.159	-0.538	0.142	-0.016	0.050
%Ent/Rec Empl.	-0.036	-0.432	0.159		0.082	-0.109	0.008	0.538
PCI	-0.369	0.186	-0.538	0.082		-0.344	0.037	0.315
%Baptist	-0.078	-0.112	0.142	-0.109	-0.344		0.591	-0.166
%Adherents	-0.202	-0.110	-0.016	0.008	0.037	0.591		0.029
Mixed Bev.	-0.023	-0.287	0.050	0.538	0.315	-0.166	0.029	