Retail Location and Transit:

An Econometric Examination of Retail Location in Prince George's and Montgomery County, Maryland

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Introduction

Transit oriented development (TOD) is a widely accepted policy objective of many jurisdictions in the United States. Much of the focus of both policy and research on TOD, however, has been on property values, rents, and residential development. There is both anecdotal and empirical evidence to suggest that the vitality of TODs and the transit boardings from any TOD depends significantly on the extent of retail development in the transit station area. We focus here, therefore, on the relationship between transit and retail location.

Specifically, we focus in this paper, on the determinants of retail location in two counties, Montgomery County and Prince George's County, Maryland, with a particular focus on the influence of proximity to rail transit stations. We proceed as follows. First we review the literature review and offer a brief history of retailing, its concentration in central cities, and its suburbanization in the post-war period drawing on two classic retail location theories. We then examine the determinants of retail location using building-level data and a rich set of locational data for Prince George's and Montgomery County, Maryland. We find that retail location is strongly influenced by access to transportation facilities, especially bus and light rail transit stops. We find also that retail location is strongly influenced by street network connectivity and proximity other retail establishment. These findings offer strong support for regional development strategies that focus on pedestrian activity centers connected by bus and rail transit.

Principles of Retail Location

Retailing has a long history and plays an important role in the structure and evolution of cities and regions. In the Medieval Era, though agricultural productivity was low, people still engaged in trade (Davis, 2011) The advent of trade led to the emergence of markets and fairs, which enhanced the city's importance and attracted more people from farm to city. The Industrial Revolution brought about mass production, which significantly reduced commodity prices. Increased specialization lead to the creation of specialty stores and department stores, and a new retail landscape. (The Store WPP, 2013)

Traditionally, most retailing takes place in central cities and main streets were historically the focal point of stores and restaurants. Hottelling, using principles of *game theory*, developed a retail location theory, often described as the competitive location model (Eiselt, Laporte, & Thisse, 1993) and illustrated in Figure 1. In Figure 1, suppose A and B are two stores selling the same products along a linear market with the equal marginal production costs. The total cost to a customer consists of two parts: product cost and the travel cost, which is proportional to distance from each store. If both A and B sell at the same price P1, then the linear market will be divided equally, and customers who live to the left of M1 will go to store A, and those who live to the right of M1 will go to store B. To compete, if store B decreases its price to P2, while store A keeps selling at P1, the market division point will move towards A, meaning A's market is shrunk and B's enlarged. (Rodrigue, Comtois, & Slack, 2013)

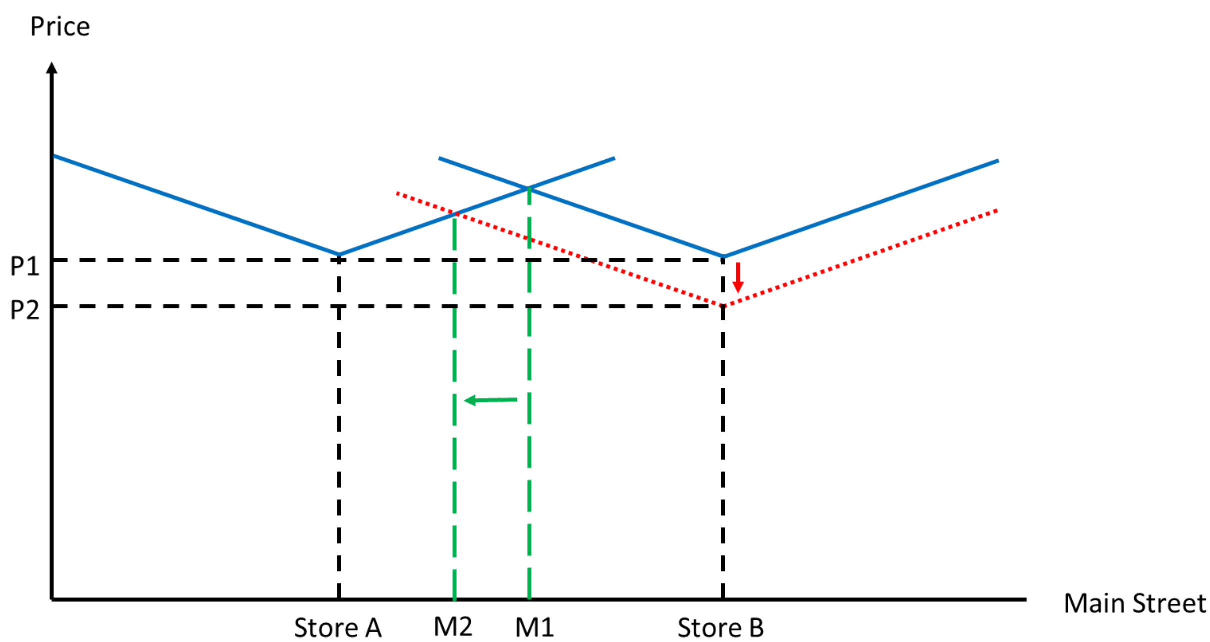

Figure 1. Hottelling's dynamic competitive location model illustration

Christaller developed a model of retail location in a two dimensional framework known as Central Place Theory. To Christaller, providing central goods and services is the major function of towns and cities. Central goods and services are defined as those provided and offered in a few cities but serve the needs of a large region. The more important goods and services a central place is provides, the higher ranking it has in the city hierarchy. The size of a central place region is determined by its market area, which is affected by factors such as the cost of transportation, the loss of weight during shipment, and the discomfort of travel. For central places of a lower level, as illustrated by Figure 2., it is best to be located at the center of triangles determined by each group of three neighboring higher-level central places.

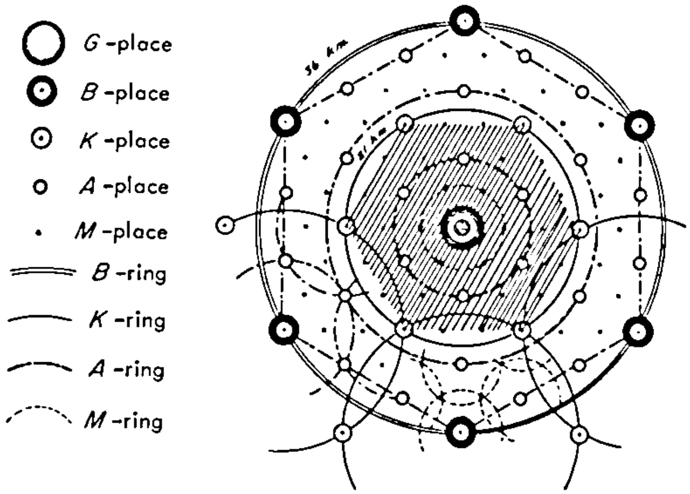

Figure 2. A system of central places according to the marker principle. (page 61)

In an expanded central place model, Christaller further proposed a framework taking traffic into account. The traffic-principle model says that how central places are connected largely depend on the importance of two destination places. If a pair of central places are both highly ranked and providing unique central goods, it is very likely that a long-haul road would connect them directly, while secondary roads and local lines link lower-level central places. The extent of long-haul traffic is also a result of the region's wealth. For a poor region, only short-haul roads are affordable and thus the road system is more random.

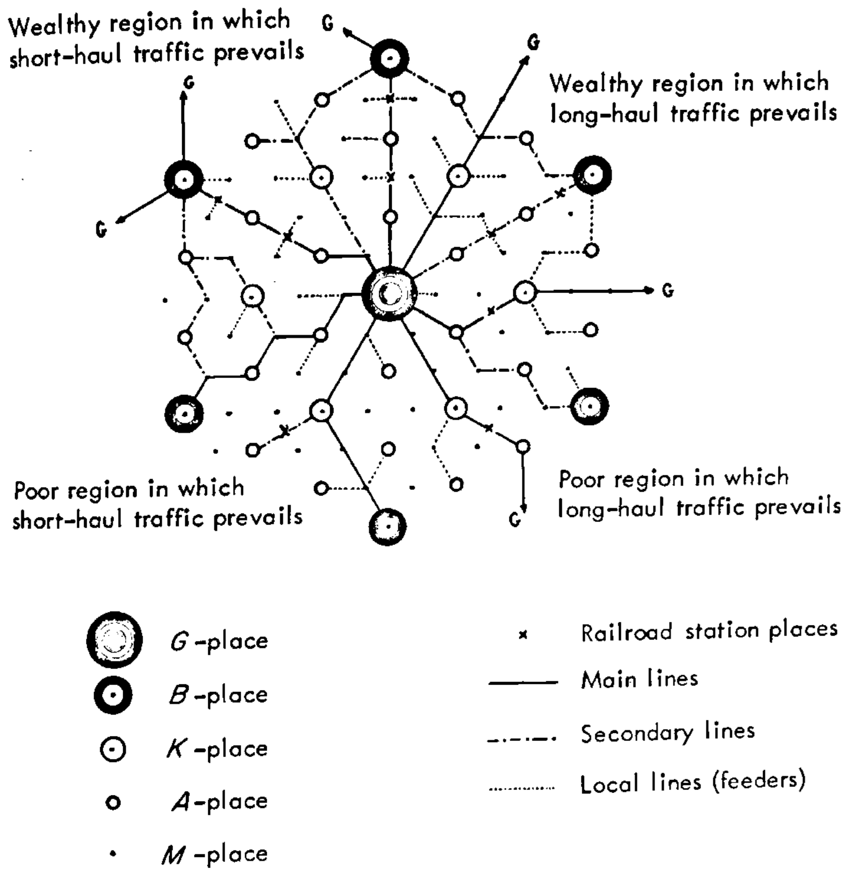

Figure 3. The traffic routes in a system of central places. (page 73)

Christaller also discussed the impact of lower travel costs on the central place system from a dynamic long-term perspective. As illustrated in Figure 3, a decreased travel cost has a twofold effect on the evolution of the central place system. On the one side, lower travel costs could lower consumer costs, giving them more money to spend on goods and services. With a lower transportation cost barrier, consumers may travel longer distances to central places. On the other hand, lower travel costs accelerate the decentralization process in which new central places could emerge. Finally, Christaller explored the impact of automobile and rail transit service. Rail transit, with its fixed routes and stations, favors the development of central places with higher importance. On the other hand, the automobile is less geographically constrained, and thus, more likely to generate decentralized development patterns.

The Suburbanization of Retail

Christaller's analysis of the impact of the automobile were prescient. The automobile and suburbanization have had major impacts on retail location (Ghosh & McLafferty, 1991) As the interstate highways and expressways were built, and as more families were able to afford a car, residents moved out of central cities to inner suburbs and exurbs. Following the relocation of their customers, since the 1950s, department stores relocated from central cities to suburban subcenters. Later, other retail establishments followed suit, including movie theatre, food stores, and restaurants, leaving central-city residents underserved.

With the large supply of low cost of land, retailers in the suburbs occupied much more space than their central city counterparts, and developed new spatial forms. Supermarkets and supercenters became the suburban version of corner store but were typically 100-times larger in size. Small retailers in the suburbs also saw significant changes. Since the 1960s, smaller-scale but more convenient shopping centers, neighborhood and community malls, which were anchored by supermarkets, emerged and sprawled quickly. Drug stores, restaurants, pet stores, and specialty stores were introduced to strip malls. Regional/super-regional shopping center, community shopping centers, and neighborhood shopping centers formed a shopping center hierarchy, each with "discrete functions, trade areas, and tenant mixes."

Starting in the late 1980s, the shopping center industry "entered the mature stage, experiencing a decrease in growth rate." The decline was due to the economic recession and the over-expansion of the industry. However, new forms of retail emerged, such as factory outlet stores, discount stores (e.g. Walmart, K-Mart, and Target), and power centers.

Since originally they were designed to meet suburban residents' need and to fit into a suburban landscape, shopping centers usually are located along highly-trafficked, arterial roadways, and form strip development pattern. Commuters who drive to work are likely to stop by retailers on their way to and from work. Regional/super-regional shopping centers are located right at high-level interstate highway exits, serving customers within large market area. Not only have suburbs been shaped by shopping centers, shopping centers have shaped suburban development patterns too. "Vacant areas near shopping malls became prime sites for housing development, particularly high density apartment complexes. Grocery stores, fast-food outlets, and other low-order retail activities gravitated to highway strips near shopping centers, taking advantage of increased customer traffic. Large shopping centers became the hubs of suburbia" (Muller 1976, in Ghosh & McLafferty, 1991, page 258).

Transit Stations and Retail Markets

In the early 1990s, the Smart Growth movement gained momentum in the United States, and called for compact and high-density development. The State of Maryland in particular, adopted a number of specific Smart Growth policies and tools including Priority Funding and Rural Legacy areas designed to encourage development in high-density urban/town centers while preserving agricultural and natural resources (Knaap, 2004). The state also expressly supports, Transit-Oriented Development (TOD), as a means of concentrating growth in transit station areas. Though definitions vary, TOD is usually defined as development within one quarter mile to one half mile of a station that features a mix of land uses, high-density development, and pedestrian friendly environments (Cervero, 2004).

Transit oriented development can serve as a catalyst for retail development. With their mixed uses, urban furniture, pedestrian-friendly environment, and bus transfer facilities, TODs encourage transit riders to spend more time in the immediate area. Retailers then benefit from the increased traffic flow. Empirical studies have shown that TODs can significantly increase land value around stations, and that transit can attract retailing and commercial development. For example, residential property values near the Dallas Area Rapid Transit light-rail station increased by 39 percent, and office building values by 53 percent (Weisbrod & Reno, 2009). In San Jose, between 1984 and 2000, the commercial rents of properties within ¼ mile of light rail stations were found 13 percent higher than those beyond ¾ mile. (Bartholomew & Ewing, 2011) A recent literature review offered the conclusion that retail land values near transit station increased between 1 to 167 percent (Fogarty, Eaton, Belzer, & Ohland, 2008).

The interaction between TODs and retail development is two directional. Research shows that the agglomeration of retail in transit station areas helps to increase transit ridership. Cervero et al. (2004), in a study of Arlington County, Virginia, found that every 100,000 square feet of additional office and retail space increased average daily boarding by 50, They also found that office and retail development has a greater effect on transit ridership than the level of transit service and the extent of residential development. (Cervero, 2004) One explanation is that retail and its auxiliary amenities, such as front windows and complete sidewalks, greatly improve the pedestrian environment near transit stations and thus attract more transit riders. This theory is supported by Loutzenheiser (1997), who studied the Bay

Area Rapid Transit (BART) system, and found that retail, among all built environment characters, is positively associated with the ratio of walking trips to transit stations. Another reason retail contributes to higher transit ridership is that retail activities help to create safer places. The safety issue has been a major barrier keeping people, particularly females, from taking transit (Loutzenheiser, 1997) .

Some retail sectors are more likely to be located near transit station than others, Using information of retail stores within the immediate adjacent areas of both rapid transit and commuter rail in Greater Toronto, Yeates and Jones found that within vicinity of heavy rail station entrances, convenience stores, coffee shops, and lottery ticket sales outlets tend to dominate retail activity; while for commuter rail, coffee kiosks, quick food, dry cleaners, and auto repair are the most common retail establishments. In addition, Yeates and Jones measured the minimum daily traffic flow necessary to support a retail store: for heavy rail, a minimum daily traffic flow of 6,600 persons is required; and for commuter rail, the minimum dropped to 1,100 (Yeates & Jones, 1998).

Besides transportation, there are other factors affecting retailer location decisions. For example, competition, labor market, rent, and financing feasibility, are other important variables. Customer demographics, including age, income, and race, matter too. For example, following the greying of baby-boomer generation, department stores stopped declining and revenue became stabilized (Wrigley & Lowe, 2002).

In sum, the location of retail establishments has received a great deal of theoretical and empirical research. Theory and empirical evidence suggest that retail location is determined by transportation costs, access to costumers, economies of scale, and the quality of the neighborhood environment. Surprisingly, however, there has been little research on retail location in transit station areas or how retail location is affected by transit. We offer new empirical evidence on these questions here. Because the state of Maryland and both Montgomery and Prince George's Counties have adopted explicit polices to foster transit oriented development, our findings offer important policy implications.

Empirical Analysis

We turn now to an empirical analysis of retail location in Prince George's and Montgomery County, Maryland. Located on the northern border of Washington, DC, Prince George's and Montgomery County are two of the most populous and politically significant counties in the state. Montgomery

County has a diverse population and is among the most wealthy and progressive counties in the nation. Prince George's county has a predominantly black population and has the highest median income of any majority-minority counties in the nation. Both benefit greatly from their proximity to Washington, DC, and host many large federal facilities. The Red line of the Washington metropolitan transit system provides service to Montgomery County and the Green, Blue and Orange line provide service to Prince George's County. The Purple Line light rail transit line will connect the two counties with the first radial transit line in the metropolitan area and is expected to break ground in 2015. For these reasons, Montgomery and Prince Georges counties represent ideal locations for exploring the influence of transit on retail location.

DATA

The unit of analysis for our research is the individual building. Our building data come from county planning departments circa 2011 for Montgomery County and 2009 for Prince George's County. We limit our analysis to buildings located in areas zoned as "mixed use" or "commercial." This reduces number of buildings in our sample from 655,961 to 21,259 in total.

Retail data come from 2012 Maryland Quarterly Census of Employment and Wages (QCEW) database. QCEW is a Federal-State cooperative program, which produces a comprehensive tabulation of employment and wage information. For each establishment, the QCEW includes information on geographic location, industrial classification codes, employment size, wage, and so on. For Maryland, the QCEW data are prepared and maintained by Maryland Department of Labor, Licensing and Regulation (DLLR). Workers included in the QCEW are either covered by Maryland State Unemployment Insurance (UI) laws or the Unemployment Compensation for Federal Employees (UCFE) program. Despite the fact that the QCEW data exclude workers not covered by unemployment insurance, the database is the best available resource to understand and to analyze economic development at the micro level. (Bureau of Labor Statistics, 2014; Maryland Department of Labor, Licensing and Regulation, 2012)

The QCEW database is for establishments in all industries. Therefore, to select retail establishments, we use the criteria that the North America Industry Classification System (NAICS) codes equal to 44, 45 or 722. Table 1 below presents a listing of these codes.

Table 1: NAICS code definitions.

NAICS code	Definition	Example
44-45	Retail trade	442 Furniture and Home Furnishings Stores 443 Electronics and Appliance Stores 445 Food and Beverage Stores 447 Gasoline Stations 448 Clothing and Clothing Accessories Stores 452 General Merchandise Stores 454 Nonstore Retailers (should be exclude?)
722	Food service and drink place	7221 Full-service restaurants 7222 Limited-service eating places

Figure 4. presents our study area, buildings, and retail establishments, with a zoom-in map of downtown Silver Spring.

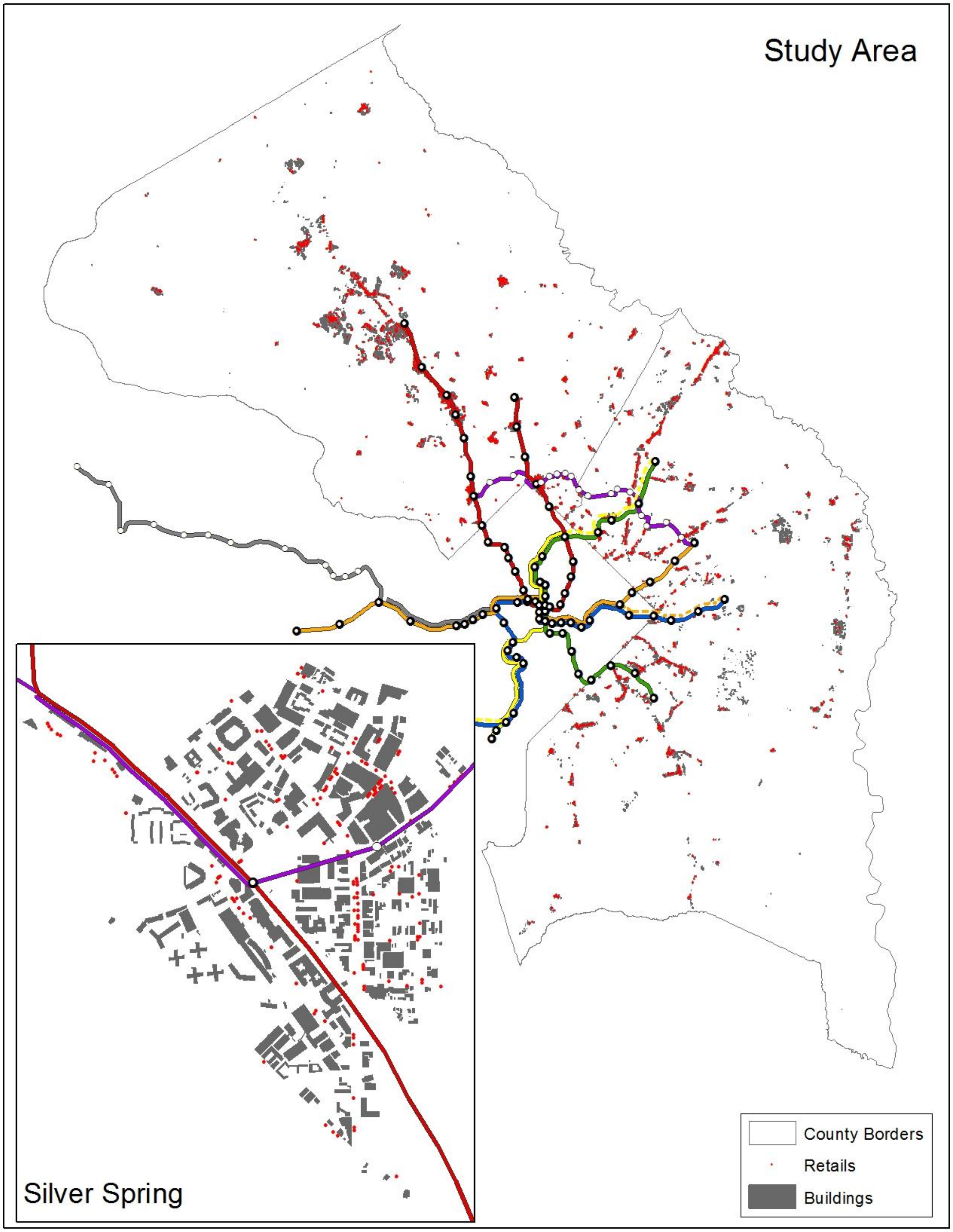

Figure 4. Study area.

VARIABLES

Based on the literature, we include four categories of independent variables in our analysis. They are market potential, transit accessibility, built environment factors, and economic interaction among retail establishments. Table 2. lists the dependent and independent variables and their sources.

Table 2. Variable list

Dependent Variables		
Category	Variable	Data source
Retail location	Binary variable whether there is retail within the building (0,1)	Montgomery and PG county planning department building shapefiles; 2012 QCEW
Independent Variables		
Category	Variable	Data source
Market potential	Black population within Block Group (BG)	EPA's Smart Location Database, original data from 2010 decennial Census, American Community Survey (ACS), Census Longitudinal Employer-Household Dynamics (LEHD), General Transit Feed Specification (GTFS), NAVTEQ NAVSTREETS,
	Asian population within BG	
	Hispanic population within BG	
	Population in poverty within BG	
	Share of renter occupied housing units within BG	
	Vacant housing units within BG	
	Senior population (age 65+) within BG	
	Total households within BG	
	Total population within BG	
	Total employment within BG	
	Total low wage workers within BG	
	Total medium wage workers within BG	
	Total high wage workers within BG	
	Housing units per unprotected acre	
	Population per unprotected acre	
	Jobs per unprotected acre	
	Total activity units (number of jobs + housing per unprotected acre)	
	Jobs within 45 minutes auto travel time, time-decay (network travel time) weighted	
	Working age population within 45 minutes auto travel time, time-decay (network travel time) weighted	
	Jobs within 45 minutes transit commute, distance-decay (walk network travel time, GTFS schedules) weighted	
Transit accessibility	WMATA metro stations within 1 km, distance-decay (walk network travel) weighted	WMATA, OpenStreetMap
	Local bus stops within 500m, distance-decay (walk network travel) weighted	WMATA & Local transit

		agencies, OpenStreetMap
	Aggregate frequency of transit service within ¼ mile of BG boundary per hour during evening peak period	EPA Smart Location Database
Physical infrastructure	Street intersection density	EPA Smart Location Database,
	Building footprint area	Montgomery and PG county planning department building shapefiles
	Street network density	EPA Smart Location Database
Economic interaction	Retail locations within 1km, distance-decay (walk network travel) weighted	QCEW, OpenStreetMap

We control for market and built environment factors by incorporating variables from the U.S. Census and the Environmental Protection Agency's (EPA) Smart Location Database, and we control for aspects of a building's physical structure using data from local planning departments. To compute our explanatory "accessibility" variables, we combine street network data from OpenStreetMap, retail location data from QCEW, and rail/bus stop data from local transit agencies using a computational framework recently proposed by Foti and Waddell (forthcoming).

In concept, Foti and Waddell's algorithm takes a set of origin points (in our case, retail firm locations) and a set of destination points (in our case, bus/rail stops and other retail locations), then computes the network-based distance from each origin to *every possible* destination. Each origin is then assigned an accessibility variable by taking the weighted sum of all destinations that fall within a specified distance, where destinations are weighted using distance decay function such that nearer destinations receive a higher weight than further ones.

Formally, each observation is assigned an accessibility score (A), where

$$A = \sum (x * e^{-\lambda * distance}) \ \forall \ Firm \in R$$

x is a destination of interest,

λ is a constant rate

$Firm$ is a retail location and

R is a maximum specified distance

We compute accessibility measures using Foti and Waddell's algorithm for fixed rail stops, bus stops, and other retail locations, each subject to an exponential decay. We use one kilometer (along a local road network) as the maximum search distance for fixed rail and retail locations, and 500 meters for bus stops.

MODEL

To better understand the nature of TOD, we test the hypothesis that walkable access to transit stops is positively related to the location of retail establishments. Toward this end, we construct a multinomial logit model in the following log-log form:

$$\ln(y) = \beta_0 + \beta_1 \ln(x_1) \dots + \beta_k \ln(x_k) + \epsilon$$

The outcome of interest is a binary variable that indicates whether a given building contains a retail establishment, which is then modeled as a function of local market characteristics, building and infrastructure characteristics, economic interaction, and transit accessibility. Log-log models are typical in the econometrics literature because they allow the estimation of binary outcomes, and coefficients can be readily interpreted as elasticities.

Given the spatial nature of the dataset, however, a number of other models could be equally appropriate. It is likely, for instance, that the data follow a spatially autoregressive structure in which the values at a single observation are influenced by the values of nearby observations. In such cases, spatial lag (SL) or spatial error models (SE) that account for spatial autroregression are typically appropriate, and have become increasingly popular in social science applications. Unfortunately, SL and SE models are extensions of linear models and have not been well adapted to generalized linear models and non-linear outcomes. To account for autoregressive properties in binary outcomes, Augustin proposed the autologistic spatial model in 1996, which has since been adopted broadly in spatial ecology and applied in other fields such as dental medicine and image analysis (Dormann 1997). Autologistic models are problematic too, however, as demonstrated by Dormann (1997) who found that they "consistently underestimate the effect of the environmental variable in the model and give biased estimates compared to a non-spatial logistic regression," and further "that autologistic regression is more biased and less reliable" than other methods available for correcting spatial autocorrelation".

Thus, although the data in our study may contain a spatially autoregressive structure, we choose to ignore such structure given the problems inherent in models that attempt to accommodate it. Instead, we contend that the log-log model is appropriate for our purposes, but we caution the reader that our coefficient estimates may be somewhat biased. We plan to explore several additional model specifications in future work.

RESULTS

Despite the caveats outline above, estimates from our retail location model show promising results. Most of the control variables have coefficients with expected signs and many are significant. Transit access appears to be strongly related to the presence of retail establishments. Bus stop accessibility and fixed rail accessibility are both highly significant (99.9%) and positively associated with the presence of retail. Transit accessibility appears to have a stronger relationship with retail firm location than does bus access. Frequency of transit service is also significant and positively correlated with the presence of retail, suggesting that simply being near to a transit station may not be sufficient to influence retail locations decisions in the absence of relatively frequent service.

Although market potential is certainly an important factor that influences the location decisions of retail firms, neighborhood demographic composition appears to be only weakly associated with the presence of retail. In other words, neither the neighborhood's workplace characteristics nor its residential characteristics appear to play a large role in determining whether retail is likely to develop. Only two variables in this category are significant at the 99% level, the presence of low wage workers, and the presence of elderly, and the correlations may be spurious.

Finally, agglomeration economies—localization in particular—appear to have strong impacts on retail location choice. Although we include only a single measure of agglomeration (access to retail within one kilometer), it appears highly significant with a relatively high magnitude. This finding is unsurprising; firms of the same industry are well known to co-locate in order to capitalize on benefits like labor pooling, shared inputs, and other positive externalities. In the transportation literature, it has also been theorized that retail development helps stimulate spatial activities and attract trips. In this framework, a retail firm may be more likely to locate near other retail firms to capitalize on the market induced by imperfect substitutions. Interestingly, measures of 'activity density' like total jobs, households and the summation of jobs and households are only weakly related to retail location.

Table 3: Determinants of Retail Location.

Category	Variable	Coefficient	Significance
	Intercept	-9.419	***
Market Potential	Black Population (within BG)	0.268	
	Asian Population (within BG)	0.698	.
	Hispanic Population (within BG)	0.297	
	Population in Poverty (within BG)	0.282	
	Share of renter occupied housing units (within BG)	0.616	
	Vacant Housing Units (within BG)	0.251	
	Senior Population (Age 65+) (within BG)	2.446	**
	Total Households (within BG)	-0.253	
	Total Population (within BG)	-0.003	
	Total Employment (Within BG)	-0.590	*
	Total low wage workers in BG	0.285	**
	Total medium wage workers in BG	0.075	
	Total high wage workers in BG	0.198	.
	Housing Units per Unprotected Acre	-0.739	*
	Population per Unprotected Acre	0.578	*
	Jobs per Unprotected Acre	-0.061	
	Total Activity Units (Jobs + Housing Units per Unprotected Acre)	0.054	
	Jobs within 45 Minutes Auto Travel Time, time-decay (network travel time) weighted	-1.309	.
	Working Age Population within 45 minutes auto travel time, time-decay (network travel time) weighted	1.578	.
	Jobs within 45 Minutes Transit Commute, distance-decay (walk network travel time, GTFS schedules) weighted	0.153	.
	Working Age Population within 45 minutes transit commute time-decay (walk network travel time, GTFS schedules) weighted	-0.166	*
Transit Accessibility	WMATA metro stations within 1km, distance-decay (walk network travel) weighted	1.022	**
	Local bus stops within 500m, distance-decay (walk network travel) weighted	0.321	***
	Aggregate Frequency of Transit Service within 1/4 mile of BG boundary per hour during Evening Peak Period	-0.094	*
Physical Infrastructure	Street Intersection Density	-0.403	***
	Building Footprint Area	0.535	***
	Street Network Density	0.324	*
Economic Interaction	Retail locations within 1km, distance-decay (walk network travel) weighted	0.737	***

Conclusion

In this paper we conducted an econometric examination of the relationship between retail location and transit accessibility. In part one, we reviewed the classical literature on urban form and retail location choice. In part two, we used data from two counties in the Washington DC suburbs to construct measures of transit and retail accessibility and constructed an econometric model to estimate the relationship between urban contextual factors and retail firm locations. The results form our analysis provide empirical support for the notion that retail firms are attracted to locations with high levels of transit accessibility. By extension, these findings suggest that investments in transit—particularly fixed rail transit—may be an effective method for stimulating retail development in metropolitan areas.

While these results are promising, two important caveats limit their inferential power. First, the data may be spatially autocorellated, thereby violating the independence assumption in classical regression and introducing bias into our estimated coefficients. In our current analysis, we are unable to account for spatial autoregression, due to limitations in existing modeling frameworks for binary outcomes. Econometric techniques in this area are advancing rapidly, however, and we plan to explore several additional model specifications.

A second important caveat concerns endogeneity. The data used in this study are cross sectional, and do not permit the consideration of time as an explanatory dimension. Thus, while our results conform largely to the tenants of classical urban theory, we are unable to disentangle the relationship between firm location and transit access. Although there appears to be a strong relationship between these two factors, we are reminded of the old statisticians adage that correlation does not equal causation, and we are mindful of the direction of our inference. We cannot determine whether the presence of transit stations induce the relocation of retail establishments or whether transit stations tend to develop in areas where retail density is already high. Future work in this area should exploit time series data to help provide guidance on these issues.

In sum, this paper presents the results from an informative but imperfect model. Transit access and retail location are positively related and investments in one may spill over to the other.

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