Economic Activity and Transportation Access

An Econometric Analysis of Business Spatial Patterns

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Several studies of transportation and economic development impacts have recognized the extent to which changes in accessibility triggered by transportation improvements may translate into business cost savings and contribute to a region's economic competitiveness. This paper specifies and empirically tests a general model that captures the intensity of business activity (at the zip code level) as a function of local and regional accessibility, agglomeration economies, and region-specific effects. The geographic area of analysis is a four-county region in Maryland. The econometric analysis establishes a significant association between transportation supply and business activity in the study area. The findings suggest a clear positive association between access to primary highway facilities and the level of economic activity. The results also confirm expectations that roads with higher functional form and capacity are likely to be spatially associated with a higher intensity of economic activity. The models described in the paper provide the basis for examining regional economic effects related to new transportation facilities.

The economic impacts of transportation improvements are not limited to direct user benefits in the form of travel time and operating cost savings. Accessibility changes triggered by transportation improvements or the construction of new facilities may translate into business cost savings, which in turn contribute to a region's economic competitiveness and to the nature and extent of economic activity in a region. Generally, investments in transportation facilities will affect the economy of a particular region through

- Lower production costs generated by travel time savings to road users (commonly addressed in travel efficiency analyses) and
- Higher relative attractiveness of the location (based on enhanced accessibility and the generation of economic growth by the location of new employers and the expansion of existing businesses).

Several studies of transportation and economic development impacts have recognized the extent to which a transportation investment may improve access to markets and by doing so influence firms' location decisions (*1–6*). These potential effects on economic activity and business decisions are expected to be greater for congested metropolitan and other regions where access costs and congestion are believed to negatively affect business activity.

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Business attraction impacts have gained attention in recent studies of transportation project evaluation (*1, 5, 7, 8*). The analysis presented in this paper is intended to examine patterns of association between business activity and transportation access in a given region and to test the hypothesis that the extent and character of transportation supply positively impact business activity, measured in terms of number of establishments (of varying sizes) in various business sectors. The econometric models developed as a basis for the analysis provide useful estimates that could be used for predicting potential changes in economic activity likely to be generated by new investments or improvements in transportation facilities.

The analysis relies on econometric models that relate measures of business activity, aggregated at the zip code level, to aggregated measures of transportation supply and accessibility. These models are developed and estimated to capture actual patterns for the area of interest, focusing on the effect of highway access on the nature and magnitude of business activity (number of establishments). The resulting models are expected to allow broad-brush prediction of the potential business growth by industry sector and employment size locating in the impacted area due to changes in accessibility brought about by contemplated transportation projects.

The remainder of the paper is organized as follows. The first section introduces theories of employment and business activity location and provides the basis for the development of a conceptual structure for the empirical analysis. The next section describes the study area and the characteristics of the business activity data used to empirically test the relationships specified in the conceptual model. Specification and estimation of the models, along with analysis of the empirical relationships, are given next, and the paper concludes with a discussion of the model's applicability for predicting the potential change in economic activity associated with contemplated investment in transportation supply.

CONCEPTUAL MODEL

An important line of investigation into transportation and economic development impacts has resulted from FHWA's 2001 publication of a guidelines document (*8*). This document examines the influence of access improvements on firms' location decisions. The conceptual foundation of these approaches recognizes that transportation investments produce economic benefits by improving a region's access to strategic markets and making it more attractive as a place to do business. This attractiveness may then result in formation of new businesses in the impacted region, relocation of outside businesses, redistribution of existing business locations, or activity expansion at the existing location (*8*).

Complete enumeration of the potential economic benefits from a transportation project, in addition to user benefits, could become extensive as second- and third-order effects and interactions are taken into account. Most empirical efforts in this area rely on measures of economic productivity and overall macroeconomic effects of transportation infrastructure expenditures (*9, 10*). Although several studies (*7, 8, 11*) have attempted to evaluate these economic development effects, data availability and other impediments such as geographic and functional aggregation constraints limit the ability to perform reliable analyses.

Besides the limited empirical efforts, there is an extensive body of literature on theories of employment and business activity location. Almost every theoretical model has recognized the importance of access in these economic decisions. From von Thünen's (*12*) negatively sloped agricultural land rent gradient model and subsequent associated monocentric models of urban structure (*13–15*), to Christaller's (*16*) central place theory applied to spatial theories of urban firm location and Losch's (*17*) hexagonal representation of market areas based on spatial competition between firms, accessibility of transportation facilities has played a key role in the formulation of these theories.

The concept of agglomeration economies also constitutes an important aspect in urban and regional economics, and particularly in firm locational analysis. Therefore, in addition to accessibility factors, this paper attempts to evaluate the influence of agglomeration economies on the presence and degree of business activity. Some authors have classified agglomeration economies as cost savings to the individual firm, which may be accrued in particular forms of internal or external economies to the firm and with different dimensions of scale, scope, and complexity (*18*). The underlying assumption of these theories is that firms experience cost savings or increasing returns when they cluster spatially. For example, employment clusters may benefit from spatial proximity, information spillovers, local nontraded inputs, and a local skilled labor pool (*19, 20*).

Additional determinants of economic activity that are not factored in accessibility and agglomeration effects might include other variables specific to projects and regions. For example, the business attractiveness of a region might be influenced by the extent of amenities, governmental services, or other state and local regulations such as tax policies and economic development programs.

In light of previous theoretical models of business and firm location, this paper specifies and empirically tests a general model that captures the relationship between the occurrence and intensity of business activity as a function of local and regional accessibility, agglomeration economies, and region-specific effects. Although informed by the variables suggested by prevailing theories and prior findings, the model specification is also influenced by available data. The following categories of variables are included in the model specification:

- Business activity characteristics: occurrence and intensity of business activity measured by density of businesses or establishments;
- Agglomeration economy characteristics: geographic clustering of firms of the same industry class in each of the other sectors in the surrounding area;
- Local accessibility characteristics: density of primary highways, arterials, connecting roads, and transit stations;
- Regional accessibility characteristics: travel time accessibility to regional intermodal transportation terminals and airports; and
- Region-specific effects: systematic variation unobserved and related to subarea-specific factors.

Figure 1 depicts the analytical framework of the relationship between business activity and road access variables that provides the basis for the empirical examination conducted in this paper.

STUDY AREA AND BUSINESS ACTIVITY DATA

The geographic area considered in the study is the four-county region of Anne Arundel, Howard, Montgomery, and Prince George's counties in the state of Maryland. These counties lie to the north and east of the Washington, D.C., area and constitute the northern and eastern suburbs and exurbs of a large and fast-growing metropolitan region.

A quick view of the study area's base economic profile shows that Montgomery County has higher incomes and wages and greater levels of job growth than the other three counties. Likewise, the economic base analysis reveals that Prince George's County has the highest concentrations of unemployment and low-wage workers. The composition of the economic base for each county differs as well: Montgomery County has greater concentrations of finance, insurance, and real estate (FIRE) and service jobs (10.8% and 56.8% of total jobs in the county, respectively); Prince George's County has greater concentrations of jobs in the retail trade (17.3% of total jobs in the county); Howard County has greater concentrations of wholesale trade jobs (6.9% of total jobs in the county); and Anne Arundel County has greater concentrations of jobs in the transportation–public utilities, construction, and primary sectors (5.3%, 13.4%, and 3.4% of total jobs in the county, respectively).

The level of aggregation at which the set of measures are considered was largely driven by data availability constraints, particularly for the dependent variable (business activity), which was available only at the zip code level (146 zip codes for the four-county region). Business activity measures were obtained from the Zip Code Business Patterns data on establishments taken from Bureau of the Census data (*21*). These business data consist of the number of establishments in each of nine employment-size classes (1 to 4 employees; 5 to 9; 10 to 19; 20 to 49; 50 to 99; 100 to 249; 250 to 499; 500 to 999; and 1,000 or more), available by North American Industry Classification System (NAICS) code, down to the six-digit level. Although longitudinal data were obtained from 1998 to 2001 for the zip codes in the study area, data from only one of the years (2000) were used, given the time-invariant properties of the independent variables and the lack of time-specific effects in the model estimation, as discussed hereafter.

For modeling purposes, establishments were grouped into three classes based on the number of employees: 1 to 9 employees; 10 to 99;

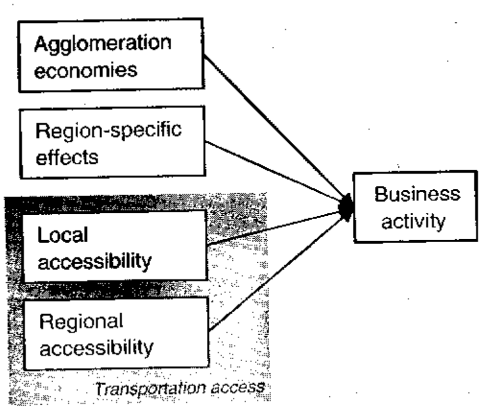

FIGURE 1 Analytical framework.

TABLE 1 Aggregation Scheme for Industry Classification

NAICS Categories	Aggregated Industry Class
Forestry, fishing, hunting, & agriculture support	Primary
Mining	Primary
Utilities	Transportation–communication–utilities
Construction	Construction
Manufacturing	Primary
Wholesale trade	Wholesale trade
Retail trade	Retail trade
Transportation & warehousing	Transportation–communication–utilities
Information	Transportation–communication–utilities
Finance & insurance	FIRE
Real estate & rental & leasing	FIRE
Professional, scientific, & technical services	Services
Management of companies & enterprises	Services
Admin., support, waste mgmt. remediation services	Services
Educational services	Services
Health care and social assistance	Services
Arts, entertainment, & recreation	Services
Accommodation & food services	Services
Other services (except public administration)	Services
Auxiliaries (exec. corporate, subsidiary, & regional mgmt.)	Services
Unclassified establishments	Undefined

and 100 or more. Industry classification was also consolidated from hundreds of NAICS codes into eight categories based on the correspondence shown in Table 1. A brief summary of the number of establishments by industry classification and by employment size for the four-county area of analysis (146 zip codes) is presented in Table 2.

MODEL SPECIFICATION

The model specifications follow, along with a detailed description of each of the independent variables:

$$Y_n^{ik} = c^{ik} + \lambda^{ik}\mathrm{AGL}_{nk} + \sum_{j=1}^{2}\alpha_j^{ik}\mathrm{RA}_{nj} + \sum_{z=1}^{3}\beta_z^{ik}\mathrm{AA}_{nz} + \gamma^{ik}\mathrm{TA}_n + \sum_{x=2}^{4}\theta_x^{ik}\mathrm{CD}_{nx} + \epsilon_n^{ik} \qquad \forall i, k$$

where

n = zip code number ($N = 146$);
Y^{ik} = a measure of business activity (dependent variable) [$i = 1$, total number of establishments per km^2; 2, number of establishments per km^2 with 1 to 9 employees; 3, number

TABLE 2 Total Number of Establishments by Industry Class and Employment Size, 2000

Aggregated Industry Class–Employment Size	Valid N	Mean	Std. Dev.	Min.	Max.
All industry types combined—total	146	433.7	495.9	8	2596
All industry types combined—1 to 9 employees	146	309.8	348.3	2	1826
All industry types combined—10 to 99 employees	146	111.9	138.7	1	714
All industry types combined—100+ employees	111	15.8	18.2	1	93
Primary	163	10.5	14.6	1	67
Construction	144	48.0	42.9	1	223
Transportation–communication–utilities	132	21.2	23.9	1	122
Whole trade	130	24.5	30.1	1	157
Retail trade	141	62.8	78.9	1	517
FIRE	136	45.5	60.4	1	399
Services	146	223.9	279.6	2	1420
Undefined	112	7.8	8.2	1	44

of establishments per km^2 with 10 to 99 employees; and 4, number of establishments per km^2 with 100 or more employees. k (aggregated industry class) = 1, total (all industry types combined); 2, primary; 3, construction; 4, transportation, communication, and utilities; 5, wholesale trade; 6, retail trade; 7, FIRE; and 8, services];

AGL_k = index of agglomeration economy effects, measured as the total number of establishments per km^2 in the adjacent zip code areas of the same industry class (k same as above); in some cases AGL_k is generic for all k and corresponds to the total number of establishments (for all industry types combined) per km^2 in the adjacent zip code areas;

RA_j = roadway access measured in total road miles per km^2 [j = 1, primary highway with and without limited access (A1+A2); and 2, secondary and connecting road (A3)];

AA_z = regional access time measured in travel time (minutes) to the main airports or intermodal terminal facilities (for all z quadratic terms are also considered) [z = 1, Dulles; 2, Baltimore/Washington International (BWI); and 3, Ronald Reagan Washington National (DCA)];

TA = transit access measured as the number of rail transit stations (MARC, Metro, and LRT) per km^2;

CD_x = a county-specific (0,1) indicator ("dummy") for each county [x = 1, Prince George's County (base comparison group); 2, Anne Arundel County; 3, Howard County; and 4, Montgomery County];

c^{ik} = the constant term; and

ϵ_n^{ik} = the error term component.

In the above equations λ^{ik}, α_j^{ik}, β_z^{ik}, γ^{ik}, and θ_x^{ik} are parameters to be estimated.

Because of the variation of area size across each zip code, all the measures of business activity (number of establishments) and some explanatory variables (roadway and transit access) were normalized by dividing the corresponding units by the zip code land area. The normalized measures of establishment density at the zip code level by industry type and employment size classification constitute the set of dependent variables for all model specifications. These variables and their summary statistics are presented in Table 3.

The index of agglomeration economy effects (AGL_k) is measured by the total number of establishments per square kilometer in the adjacent zip code areas, for each zip code. This total number does not include the establishments in the actual zip code. Two different definitions of this index were used, and the selection of either of those for a particular model specification is an empirical matter; the definition that best helps to explain the variance of the corresponding business activity dependent variable was retained in the model. The first index definition consists of the total number of establishments of the same industry class per square kilometer in the adjacent zip code areas. The other index definition differs from the first in that it is generic for all industry types and corresponds to the total number of establishments in all industry classes per square kilometer in the adjacent zip code areas. Attempting to uncover the different types of agglomeration effects that may accrue to the businesses under analysis is not a straightforward task. Moreover, inferring the effects that are attributed to each form or dimension of the agglomeration economy concept is even more complicated when the analysis is based on aggregated data (at the zip code level) and not at the firm level. However, the operationalization of the two agglomeration economy effects adopted in this study attempts to proxy for two forms of agglomeration economies: localization and urbanization economies.

In particular, the estimated proxy effect of the industry-specific agglomeration index is expected to be related to localization economies, which are external to the firm but internal to the industry. This concept is similar to the one used by other authors to describe the common location of independent firms in the same industry (*22*), also termed industrial districts (*23*). Localization economies are directly associated with the spatial concentration of like firms and are basically triggered by the advantages of having access to a pool of labor, specialized services, and knowledge spillover (*24–26*). A spatial concentration of firms from different industries is more likely to be associated with urbanization economies, another type of externality-based agglomeration economies (external to the firm and the industry). Urbanization economies are also directly associated with the spatial concentration of firms, but with ones from different industries, and are triggered by access to municipal services, public utilities, transportation and communication facilities, and a variety of other services (*27–29*). This effect is expected to be captured by the generic agglomeration index.

Road access (RA_j) is a set of roadway and highway accessibility variables measured in total road miles per square kilometer. The density of each roadway classification within each zip code was calculated using geographic information systems. Road classification is based on the roads' functional and geometric characteristics and nominal capacity. This differentiation comes from ESRI's Census 2000 TIGER/Line data (*30*), which classifies each roadway category as follows:

- Primary highway with limited access. Interstate highways and some toll highways are in this category (A1) and are distinguished by the presence of interchanges. These highways are accessed by way of ramps and have multiple lanes of traffic. The opposing traffic lanes are separated by a median strip.
- Primary road without limited access. This category (A2) includes nationally and regionally important highways that do not necessarily have limited access. It consists mainly of U.S. and state highways but may also include some county highways that connect cities and larger towns. A road in this category may have intersections with other roads, be divided or undivided, and have multilane or single-lane characteristics.
- Secondary and connecting road. This category (A3) includes mostly state and county highways that connect smaller towns, subdivisions, and neighborhoods. The roads in this category generally are smaller than roads in category A2, must be hard-surface (concrete or asphalt), and are usually undivided with single-lane characteristics. These roads usually have a local name along with a route number and intersect with many other roads and driveways.

Although A1 and A2 were considered separately in the initial analysis, the final model estimation only uses a combined measure for primary highways with and without limited access (A1+A2), given the lack of statistically significant difference between the coefficient estimates when the two are used separately.

Among the multimodal regional accessibility variables, airport access (AA_z) is measured as the travel time (in minutes) in the a.m. peak time period (for 2000) from each zip code to the main airports or intermodal terminal facilities in the metropolitan region. Travel times were obtained at the traffic analysis zone (TAZ) level from the Travel Demand Model of the metropolitan region (*31*) and were averaged for those TAZs falling within each zip code. Travel times for all the intermodal terminal facilities listed in Table 4 were initially obtained. However, the final model specifications include only travel times (and associated quadratic terms) for the main airports in the region: Dulles, BWI, and DCA. Although these variables were named as access to the main airports, some of the other intermodal terminal facilities either coincide spatially or are located in an adjacent TAZ to one of the airports. Therefore, the effect of these access variables will

TABLE 3 Summary Statistics for All Dependent Variables (for All *i* and All *k*) and AGL

Variable (Y^{ik})	Valid *N*	Mean	Std. Dev.	Min.	Max.
$k = 1$ (total; all industry types combined)					
Estab./km²—total	146	19.234	24.997	0.224	163.846
Estab./km²—1 to 9 employees	146	13.704	17.669	0.163	115.175
Estab./km²—10 to 99 employees	146	5.012	6.990	0.041	43.217
Estab./km²—100+ employees	146	0.518	0.844	0.000	5.455
Estab./km² (agglomeration)	146	15.835	16.968	0.224	113.465
$k = 2$ (primary)					
Estab./km²—total	163	0.523	1.003	0.003	7.937
Estab./km²—1 to 9 employees	163	0.305	0.576	0.000	3.810
Estab./km²—10 to 99 employees	163	0.183	0.448	0.000	3.492
Estab./km²—100+ employees	163	0.034	0.107	0.000	0.870
Estab./km² (agglomeration)	163	0.346	0.408	0.004	1.971
$k = 3$ (construction)					
Estab./km²—total	144	2.143	2.629	0.041	17.500
Estab./km²—1 to 9 employees	144	1.531	1.907	0.000	17.500
Estab./km²—10 to 99 employees	144	0.561	1.004	0.000	7.143
Estab./km²—100+ employees	144	0.051	0.132	0.000	1.034
Estab./km² (agglomeration)	144	1.552	1.127	0.041	5.456
$k = 4$ (transportation–communication–utilities)					
Estab./km²—total	132	0.963	1.483	0.012	10.000
Estab./km²—1 to 9 employees	132	0.675	1.158	0.000	10.000
Estab./km²—10 to 99 employees	132	0.246	0.439	0.000	2.587
Estab./km²—100+ employees	132	0.043	0.090	0.000	0.599
Estab./km² (agglomeration)	132	0.671	0.657	0.020	3.824
$k = 5$ (wholesale trade)					
Estab./km²—total	130	1.132	1.537	0.017	7.460
Estab./km²—1 to 9 employees	130	0.697	0.860	0.000	4.444
Estab./km²—10 to 99 employees	130	0.402	0.768	0.000	3.889
Estab./km²—100+ employees	130	0.033	0.110	0.000	1.111
Estab./km² (agglomeration)	130	0.836	0.666	0.027	3.589
$k = 6$ (retail trade)					
Estab./km²—total	141	2.658	3.477	0.018	17.327
Estab./km²—1 to 9 employees	141	1.749	2.319	0.018	11.198
Estab./km²—10 to 99 employees	141	0.831	1.112	0.000	5.963
Estab./km²—100+ employees	141	0.078	0.121	0.000	0.621
Estab./km² (agglomeration)	141	2.188	2.188	0.041	10.008
$k = 7$ (FIRE)					
Estab./km²—total	141	2.658	3.477	0.018	17.327
Estab./km²—1 to 9 employees	141	1.749	2.319	0.018	11.198
Estab./km²—10 to 99 employees	141	0.831	1.112	0.000	5.963
Estab./km²—100+ employees	141	0.078	0.121	0.000	0.621
Estab./km² (agglomeration)	141	2.188	2.188	0.041	10.008
$k = 8$ (services)					
Estab./km²—total	146	9.885	14.157	0.041	99.301
Estab./km²—1 to 9 employees	146	7.201	10.165	0.000	67.902
Estab./km²—10 to 99 employees	146	2.428	3.718	0.000	27.832
Estab./km²—100+ employees	146	0.256	0.479	0.000	3.566
Estab./km² (agglomeration)	146	7.963	9.228	0.041	50.934

TABLE 4 Intermodal Terminal Facilities in Metropolitan Region

Name	Type[1]	Mode Type[2]	City	State
Emery Forwarding, Washington, D.C.	Air	Air & truck	Sterling	VA
Sky Courier	Air	Air & truck	Sterling	VA
B and T Air Express	Air	Air & truck	Glen Burnie	MD
Washington Dulles International Airport	Air	Air & truck	Dulles	VA
Baltimore/Washington International Airport	Air	Air & truck	BWI Airport	MD
Reagan Washington National Airport	Air	Air & truck	Washington	DC
NS, Alexandria, Va.	Rail	Rail & truck	Alexandria	VA
Madison Warehouse Corp., Baltimore, Md.	Rail	Rail & truck	Baltimore	MD
Easton Clearing	Rail	Rail & truck	Bealeton	VA
Fritz Company	Rail	Rail & truck	Hanover	MD
C & S Paper Storage	Rail	Rail & truck	Washington	DC
Meridian Moving and Storage	Rail	Rail & truck	Fairfax	VA
Yellow, Manassas, Va.	Truck	Truck-port-rail	Manassas	VA
USPS-AMC/AMF-Linthicum, Md.	Air	Air & truck	Linthicum	MD
USPS-HASP-Capital Beltway HASP, Md.	Truck	Truck & truck	Capital Beltway	MD
USPS-P and DC-P and DF, Dulles, Va.	Truck	Truck & truck	Dulles	VA

[1]Type: Name of the function of the primary function of the facility.
[2]Mode type: Defines all the modes that are affiliated with this facility.
SOURCE: National Transportation Atlas Databases, 2003.

include the combined effect of several terminal facilities. Figure 2 depicts one example of the access travel time from each of the TAZs to the TAZ where Dulles airport is located.

The last independent variable that captures transportation access is the transit access (TA) variable, measured as the number of rail transit stations (e.g., MARC, Metro, and LRT) per square kilometer within each zip code. In summary, the model specification with travel time access to airports and intermodal terminal facilities, as well as local access to rail transit stations and roadways, closely captures the theoretical aspects of multimodal accessibility to labor, consumers, and suppliers described previously in the conceptual model. These variables combine both accessibility to local transportation facilities and accessibility to regional intermodal transportation terminals. Table 5 presents summary statistics for the set of RA, AA, and TA variables for the four-county area of analysis.

Finally, any systematic variation in business activity that is unobserved or not explicitly captured by the other variables in the model specification and is systematically related to county-specific factors is expected to be captured by the county-specific indicator ("dummy") variables. It was previously mentioned that there may be other variables in addition to accessibility and agglomeration effects that affect the observed economic activity. For example, business activity in a given region may be influenced by amenities, governmental services, or other state and local regulations such as tax policies and economic development programs that may differ across counties. If these county-specific effects are present and have the potential to affect business economic activity systematically across counties, these effects will be reflected in the estimated coefficients for the county-specific indicator variables (CD_x). These are essentially county-specific constant effects. Figure 3 graphically depicts a summary of most of the variables included in the model specification.

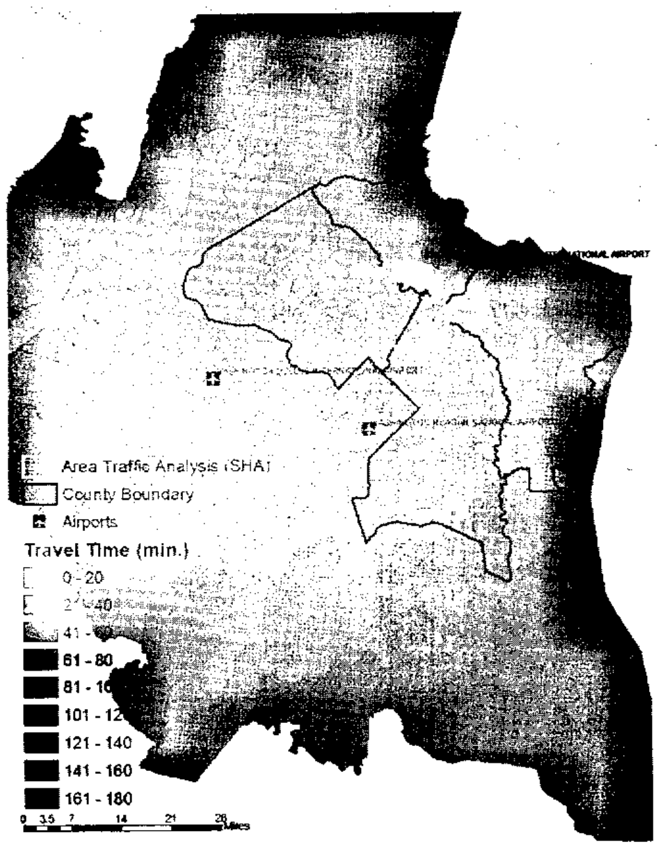

FIGURE 2 Travel time (in minutes) in a.m. peak period to Dulles (for 2000).

TABLE 5 Summary Statistics for Transportation Access Independent Variables (RA, AA, and TA)

Variable	Valid N	Mean	Std. Dev.	Min.	Max.
RA_j					
A1 (road miles/km²)	146	0.046	0.085	0.000	0.506
A2 (road miles/km²)	146	0.047	0.084	0.000	0.452
A1 + A2 (road miles/km²)	146	0.093	0.123	0.000	0.506
A3 (road miles/km²)	146	0.348	0.332	0.000	2.052
AA_i					
Dulles (min.)	146	76.938	18.997	31.400	121.000
BWI (min.)	146	59.706	19.857	13.600	113.000
DCA (min.)	146	63.932	17.342	30.875	96.000
TA					
Transit (stations/km²)	146	0.017	0.043	0.000	0.213

MODEL ESTIMATION

This section presents the estimation results for the models discussed in the preceding section. The coefficients of the explanatory variables included in the model specification are estimated using standard econometric techniques—in this case, ordinary least squares (OLS) with heteroskedasticity-robust asymptotic variance estimators (*32, 33*). The coefficient estimates represent the relative effect of the accessibility measures on business activity density, as observed at the zip code level. Particular attention is devoted to the estimates of primary highway access (A1+A2).

The model specification was estimated for all employment size classifications and for all industry classes. Table 6 summarizes the most parsimonious specifications (i.e., those with the fewest number

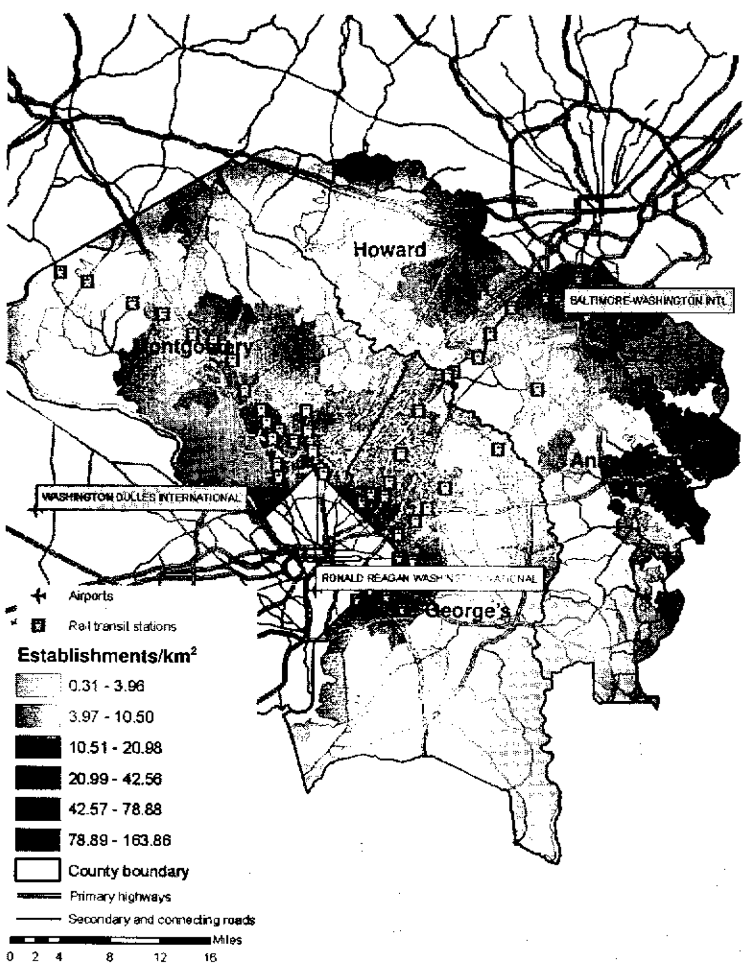

FIGURE 3 Total business activity density and transportation access.

TABLE 6 Estimated Models for All Industry Types Combined (k = 1)

i =	1 Number Estab./km² Total		2 Number Estab./km² 1–9 Employees		3 Number Estab./km² 10–99 Employees		4 Number Estab./km² 100+ Employees	
	Coefficient	t-Value	Coefficient	t-Value	Coefficient	t-Value	Coefficient	t-Value
Agglom_generic	0.292**	2.31	0.271***	3.13				
A1 + A2_road	55.250***	3.95	34.898***	3.65	15.264***	4.23	2.686***	5.04
A3_road	8.985*	1.97	6.435**	2.06	2.512*	1.88	−0.044	−0.24
Dulles	−2.659***	−3.84	−1.888***	−3.98	−0.624***	−4.38	−0.050*	−1.75
Dulles²	0.015***	3.57	0.010***	3.72	0.003***	3.81	0.000**	2.33
BWI	0.606*	1.86	0.516**	2.32			0.037	1.11
BWI²	−0.005**	−2.03	−0.004**	−2.41			0.000*	−1.83
DCA	1.511**	2.35	1.169***	2.66				
DCA²	−0.010**	−2.06	−0.008**	−2.34				
Transit	168.073***	4.98	111.821***	4.84	51.105***	4.98	6.899***	5.16
Anne Arundel							0.223	1.15
Howard							0.832***	3.13
Montgomery							0.527	1.56
Constant	47.326	1.32	26.654	1.09	28.361	4.92	0.873	0.91
Observations	146		146		146		146	
Adjusted R^2	0.6405		0.6632		0.5564		0.5054	

*significant at 10%; ** significant at 5%; *** significant at 1%
Robust t statistics – standard errors

of statistically significant variables) for each model with all industry types combined ($k = 1$) along with the corresponding coefficient estimates, t-statistics, and the statistical significance test for each coefficient. All models were statistically significant at the 99% confidence level ($p < .001$ for the F-test). On average, the model for all industry types combined and total number of employees ($i = 1$ and $k = 1$) explains more than half of the variability of the business density at the zip code level for the four-county region of analysis (adjusted $R^2 = 0.64$). Figure 4 shows an example of the behavior of the residuals of this model ($i = 1$ and $k = 1$). This analysis helped to identify heteroskedasticity in the error terms of each model. In cases of confirmatory evidence by diagnostic tests, such as for Montgomery and Prince George's counties in the figure, heteroskedasticity-robust asymptotic variance estimators are used in the model estimation process.

A particularly notable finding of this analysis is the clear positive association between access to primary highway facilities and the level of economic activity in a given geographic area. This is evidenced by the sign, magnitude, and statistical significance of the road access variables included in the model specification. The positive signs of these coefficients confirm that the more roadway access, the higher the business density in the zip code area. The magnitude of the coefficient estimates suggest that primary highways (with and without limited access) have a much larger impact than secondary and connecting roads. These results confirm expectations that roads with higher functional form and capacity are likely to be spatially asso-

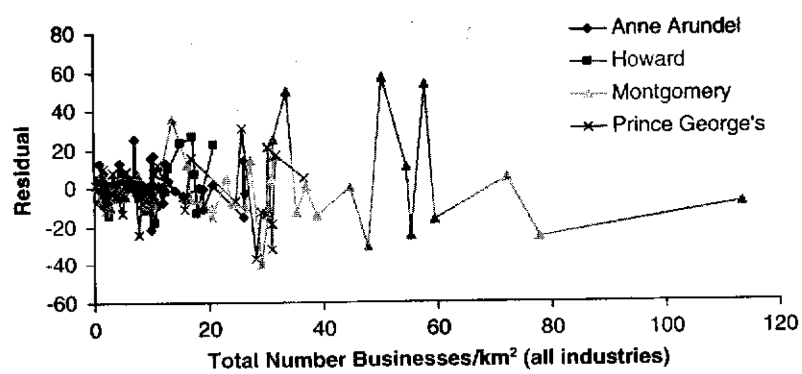

FIGURE 4 Behavior of residuals for business density models at zip code level (all industry types combined and total number of employees).