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Mixed land use is the combination of residential and commercial type properties within the same community. In suburban areas, zoning codes maintained separate residential and commercial areas, but recently mixed land use has become more popular. This paper examines the effect of mixed land use on the surrounding residential home values using ordinary least squares (OLS) regression to estimate a housing demand function. The equation is estimated using data for all residential properties in Montgomery County, Maryland assessed for value in 2016. The results indicate that mixed land use may have a negative relationship with residential home value assessments.

Montgomery County, Maryland, is a vibrant suburban community located just north of Washington, D.C. Close to the East Coast, its first settlers date back to 1715. It was mainly a farming community that later established canals and railroads. As shown in Figure 1, population remained low throughout the nineteenth century. However, in the 1930s there was a spike in the population. The population nearly doubled to over 83,000 with the increased federal jobs under President Franklin Roosevelt's New Deal Program (Cavicchi, 2001). Along with the development of automobiles, suburban communities developed close to the Washington, D.C. border. Commercial development followed shortly after and the resulting landscape separated residential neighbors from commercial centers causing a heavy reliance on automobiles.

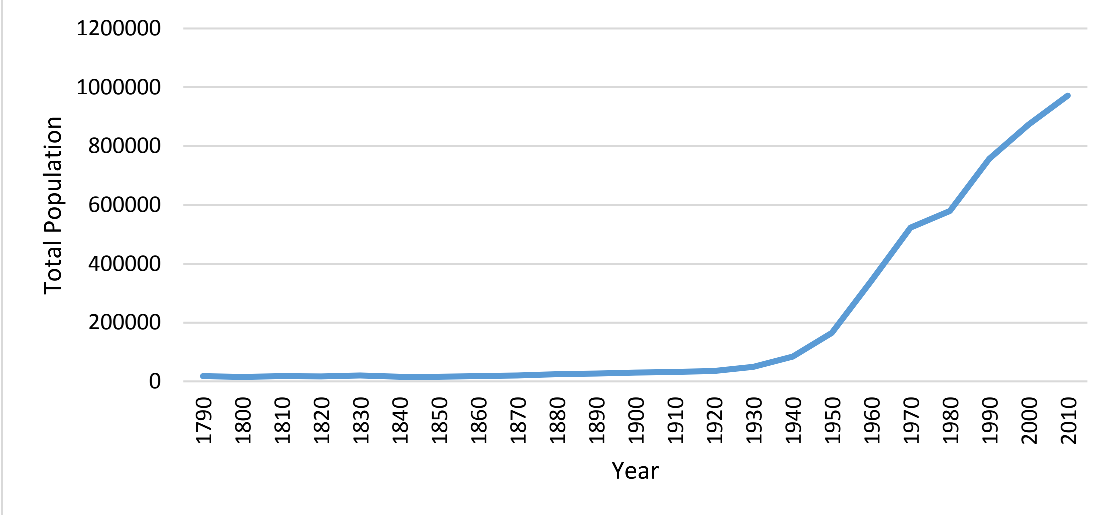
Today, Montgomery County is a thriving community with a population of over 1,000,000 residents (Census 2010). With a density of almost 2,000 residents per square mile (Census, 2010), the county is the most populated and the densest in the state. Over 90% of the population who is over 25 has a high school diploma (American Community Survey, 2011-2015) making it the most educated county as well. The median household income is over $99,000 (American Community Survey, 2011-2015) which is well above the national median household income of nearly $52,000 (American Community Survey, 2011-2015). All of these characteristics indicate that Montgomery County is a wealthy, highly educated, urbanized community with a strong demand for housing.

The county's current growth is close to the county's center, specifically around interstate I-270. Figure 2 shows current clustering of housing in the county. While the county shows an increasingly urban environment, there are still efforts to protect the rural land of the county. Cavicchi (2001) notes when observing settlement patterns in the 21st century, "one third of the county's land, about 93,000 acres, is protected farmland in the Agricultural Reserve." However, the intensive development of residential and commercial lands shows no signs of slowing down. Montgomery County must look for new development strategies that can support the dual nature of a rural and urban environment.

One approach Montgomery County has turned to is mixed land use. Mixed land use is one of The Environmental Protection Agency's (EPA) ten principle strategies that promote sustainable development for growing communities and protecting the environment. It creates communities where commercial and residential spaces are in close proximity, sometimes even within the same building. Since 2007, Montgomery County has integrated Smart Growth into development planning (Leatham and Montenegro, 2014). The goal is to use mixed land use to encourage walkable communities that advocate combining commercial and residential areas. Using mixed land use has the potential to attract new residents and yield new growth in already urbanized areas or development in new communities without large amounts of land.

Figure 1

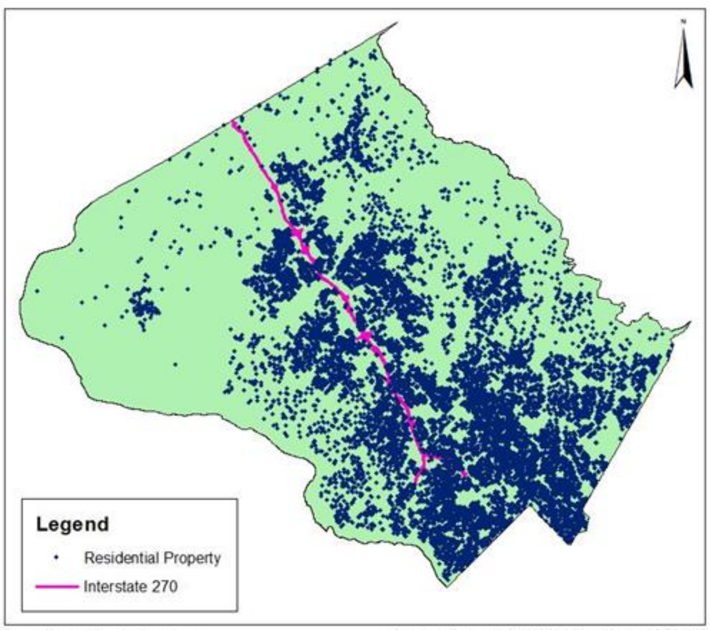
Population Growth (1790-2010)



Source: Maryland State Data Center, Census

Figure 2

Residential Properties in Montgomery County



Data Source: Montgomery County Planning, Maryland Planning

As the demand for housing continues to expand in response to the growing population, the question then becomes if mixed land use effects this housing market. However, the economic effects of mixed land has very little empirical analysis. Smart Growth suggests that mixed land use can both protect the environment and promote economic growth (EPA), but the few articles published by the EPA, only address environmental impacts. There are a small number of studies on mixed land use including Yan Song's (2004) research on single family residential neighborhoods. She reports that existing neighborhoods see an increase in home values with the addition of nonresidential use properties within the community. This implies residents have a positive response to mixed land use. However, Song's study is limited to properties built within neighborhoods and does not thoroughly analyze commercial and residential mixed properties. Montgomery County has applied mixed land use development on a larger scale and in more varied ways. With the increased complexity, it is important to consider technologies that can best assist analysis.

The advancement of Geographic Information Systems (GIS) has vastly improved methods to create quantifiable measures used in housing demand. In another analysis on mixed land use, Delisle (2013) uses GIS to observe the effect of mixed land use on commercial properties. His study finds that commercial tenants have a negative response to mixed land use. The use of GIS can better answer urban development questions and is critical to studies analyzing mixed land use. However, Delisle's focus on commercial properties is limited due to the nature of Montgomery County's development, which is strongly influenced by residential growth. The important question then becomes whether mixed land use effects residential home values. This paper addresses the question through Geographic Information Systems (GIS) and regression analysis to determine the relationship between mixed land use and residential home values.

The Model

Theoretical Perspective

Models for housing demand can be traced back to Rosen (1974) deriving a demand model from observed prices and consumer preferences. His work is now commonly used as the basis of most housing demand models. More recent research supports Rosen's theory specifying typical determinants as income, population, affordability, price of substitutes, and expectations (Mourouzi-Sivitanidou, 2011).

It is common for housing demand models to suffer from omitted variables since consumer preference is difficult to fully measure depending on the area of study. Song's (2004) conclusions further define a typical housing demand model at the county level that can be summarized as a function of home values in the form shown in equation [1].

$$Home\ Value = f\ (home\ characteristics, location, public\ service, amenities, socioeconomic, neighborhood\ design, mixed\ use) \quad [1]$$

The function is focused on residential home values and has application in a similar market (Song, 2004). Home characteristics are physical attributes of the home itself. Location is where a home is relative to places of work. Variables measuring this characteristic should focus on cities and municipals where there is a high concentration of employment. Public service is the condition of government provided services. Amenities are areas of interest for consumers that include proximity variables. Socioeconomic factors include demographic information within communities. Neighborhood design includes physical layout of the community such as roads and density. Mixed land use is the focus of this research and more specifically the effect of mixed land use on residential home properties.

The application of GIS is necessary to create quantitative variables related to distance within a housing demand model (Delisle, 2013). Delisle emphasizes the uniqueness of the tool in empirical analysis while also ensuring its validity as an accurate measure for variables. In this analysis, measures of distance are created through geographic information of residential property location and the other characteristics represented in function [1]. The process includes a combination of buffers to create the numerical information and spatial joins, to append the created information to each residential property in the dataset.

Housing Demand Function Equation

The housing demand function [1] is estimated as follows

$$HOME\ VALUE_i = \beta_0 + \beta_1(SIZE)_i + \beta_2(FOOTAGE)_i + \beta_3(DC)_i + \beta_4(MUNI)_i + \beta_5(SCHOOL)_i + \beta_6(REC)_i + \beta_7(METRO)_i + \beta_8(WHITE)_i + \beta_9(INCOME)_i + \beta_{10}(DENSITY)_i + \beta_{11}(ROAD)_i + \beta_{12}(NEARROAD)_i + \beta_{13}(SHOP)_i + \beta_{14}(MIXED)_i + \beta_{15}(NEARMIXED)_{ni} + \varepsilon_i \quad [2]$$

Where β_0 is the constant, $\beta_n{}'s$ are the variable coefficients and ε is the error term. Due to the simplistic nature of this equation, Ordinary Least Squares (OLS) is an appropriate estimation of this model. This technique is typical for housing demand models seen estimation in Song's (2013) and Delisle's (2001) model. The variables are described in Table 3.

Sources for data include Montgomery County's GIS Department and their Planning Department at the parcel level. These sources provide geographic information on county's physical design as well as detailed characteristics for residential home properties. The census also provides housing and demographic data. This dataset uses Census 2010 and 2011-2014 American Housing Survey. Data is also available from Maryland's Planning Department's public datasets to supplement missing information from the county departments.

To estimate the effect of mixed land use, the housing demand function is defined with the variables found in Table 1 with descriptive statistics in Table 2.

Home value is measured as the assessed home estimation value yielded using the Maryland Planning algorithm, -CAMA. This measure was chosen above all others due to the cross sectional nature of this study. The last estimates occurred in 2015, after the change in zoning ordinance. This is measured in 10,000 of dollars in the regression model. The data was capped at 2,000,000 dollars. The observations removed are confirmed whole building assessments instead of individual properties. There were single family homes valued at 2,000,000, hence where the cap was placed. There was not an easy method to determine if lesser values were whole building assessments. It is assumed that all values remaining in the dataset are individual properties.

Housing characteristics have two measures: SIZE and FOOTAGE. SIZE is the number of acres owned with the property. Zeros are included for properties such as apartments, where owners do not have individually owned land. It is expected that larger properties will have higher home values. FOOTAGE is the square feet of the principle structure; basements are not included. It is expected larger homes have higher value and therefore will have a positive effect on home values.

The variables DC and MUNI measure locations in the home value function. DC is a home's distance in .5 mile intervals from Washington, D.C. The distance is quantified using GIS. MUNI is a home's distance in .5 mile intervals from municipals including Rockville, Bethesda, Laytonville, etc. The variable also uses GIS for these measures. Homes that are closer to urban areas, and therefore closer to major employment centers, will have higher home values. As homes are further away from D.C and municipals, their value will drop. Therefore, DC and MUNI are both expected to have negative coefficients.

Table 1 Specifications of Variables

	Definition
Dependent variable	
Home Value ($)	Current full market total value (land value plus improvement value in $) (assessed 2015)
Independent variables (expected sign)	
SIZE (+)	Land area converted to acres of the lot
FOOTAGE (+)	Foundation square footage of the principal structure
DC (-)	Distance to Washington, DC. (Interval in 0.5 miles)
MUNI (-)	Distance to municipals (Interval in 0.5 miles)
SCHOOL (-)	Distance in miles to Elementary schools (Interval of .5 miles)
REC (-)	Distance to recreation center (Interval in 0.5 miles)
METRO (-)	Distance to metro stations (Interval in 0.5 miles)
WHITE (+)	Percent of non- White Hispanics to total population of block group
INCOME (+)	Median household income in the past 12 months (in 2012 INFLATION-adjusted dollars)
DENSITY (-)	Number of Households divided by the area of the census block (square miles)
ROAD (-)	Distance in miles to major roadways(Interval in 0.5 miles)
NEARROAD (-)	Homes within 400 feet of major roads = 1, otherwise = 0
SHOP (-)	Distance in miles to shopping center (Interval in 0.5 miles)
MIXED (+/-)	Homes zoned as Mixed land use = 1, otherwise = 0
NEARMIXED (+/-)	Homes within .5 miles of mixed land use = 1, otherwise = 0

Note: the value in parentheses is the expected value of the independent variable coefficients

Public service includes SCHOOL, which measures a home's distance in .5 mile intervals to the nearest elementary school using GIS. School accessibility is important for families and an area's education system can raise home values if it is good. Homes that are close to schools are more likely to have a higher value than homes further away. SCHOOL is expected to have a negative coefficient as homes increase in distance.

There are two variables to measure amenities, REC and METRO. Areas of recreations are for leisure activities and are thought of as positive areas. Homes that are closer to these areas of activity will have higher home values. The Metro is a way to access areas further away including DC and municipals, without using a car. Homes that are close to metros see the stations as a positive because it provides an alternative mode of transportation. Both REC and METRO will have negative coefficients, home values decrease the further away a home is from these locations.

Socioeconomic characteristics include WHITE and INCOME. WHITE is the total non-Hispanic white population divided by the total population. It is expected that more homogenous areas, in this case white, will see higher home values. The expected coefficient is positive. INCOME is the median household income in the past 12 months. Owners with higher incomes are more likely to purchase homes with a higher value. INCOME is expected to have a positive coefficient.

Table 2 Means and standard deviation of variables

Variable	Mean	Standard deviation
HOME VALUE (+)	446,279.68	302982.36
SIZE (+)	0.34	3.14
FOOTAGE (-)	1815.51	1257.80
DC (+)	2.64	1.46
MUNI (-)	1.95	1.63
SCHOOL (-)	0.87	0.44
REC (-)	1.54	0.92
METRO (-)	3.27	2.01
WHITE (-)	0.53	0.21
INCOME (-)	109,830	46,236
DENSITY (-)	2703	3443
ROAD (-)	0.64	0.32
NEARROAD (-)	0.15	0.36
SHOP (-)	1.03	0.68
MIXED (+/-)	0.06	0.26
NEARMIXED (+/-)	0.52	0.50

DENSITY ROAD, NEARROAD, and SHOP are variables for neighborhood design. DENSITY is the number of households per square miles. As neighborhoods become more crowded, less space is available and respective home values are expected to drop. The sign is expected to be negative. ROAD is a home's distance in .5 mile intervals from a major roadway, measured using GIS. SHOP is a home's distance in .5 mile intervals from a shopping center, measured using GIS. A household's proximity to roads and shopping centers will increase the value due to easy accessibility. The coefficients are expected to have negative signs as a home's distance increases. NEARROAD is a dummy variable where homes within 400 feet of a road are given a value of one, otherwise it has a value of zero. Since roads can be loud and take away privacy, homes that are in extreme close proximity will have lower home values. The expected sign for NEARROAD is negative.

Empirical Results

Determinants of Home Value

The regression results are reported in Table 3. The table reports the variable's estimated coefficient and their robust standard errors. Overall, the results indicate explanatory variables explain 68 percent of variance in the housing demand function. The model is significant at the p ≤ .01.

Table 3 Equation Regression coefficients (dependent variable = HOME VALUES

Variable	Coefficient	Robust Standard Error
SIZE (+)	-0.009	0.075
FOOTAGE (+)	0.012***	0.001
DC (-)	-2.550***	0.120
MUNI (-)	-0.913***	0.070
SCHOOL (-)	0.913***	0.297
REC (-)	-1.667***	0.169
METRO (-)	-1.007***	0.071
WHITE (+)	11.55***	0.681
INCOME (+)	2.545***	0.125
DENSITY (-)	-0.0003***	0.00
ROAD (-)	-2.120***	0.371
NEARROAD (-)	-2.745***	0.471
SHOP (-)	1.758***	0.346
MIXED (+)	-3.517***	0.817
NEARMIXED	1.313***	0.221
Constant	7.44***	0.918

F-State= 3062
Adjusted R^2 = 0.68
Number of observation = 20,976

*** denotes significance at the 1% level, ** denotes significance at the 5% level, * denotes significance at the 10% level

The variables MIXED and NEARMIXED can best help answer the main question for this paper. MIXED has a negative coefficient and is statistically significant. A negative coefficient suggests that if a home is zoned as mixed land use, there is a decrease in that home's value by $35,171. This is a very large negative effect compared to the rest of the variables tested. NEARMIXED, on the other hand, has a positive coefficient and is also statistically significant. The positive coefficient suggest homes located within .5 miles of mixed land use zones see an increase of home values by $13,135.

For the variables that measure housing characteristics, SIZE has a negative coefficient, opposite of what is expected, but also statistically insignificant. The county's significance to D.C may outweigh consumer preference for bigger lots. In this market in particular, the size of the yard is insignificant. FOOTAGE on the other hand, has a positive coefficient and is statistically significant. This matches the expected hypothesis.

The variables to measure locations, DC and MUNI, have negative signs and are significant following the theory. DC has a much larger effect of over 25,000 dollars in value when a house is another .5 miles away, while increased distance from municipals only decrease value by less than 10,000 dollars for every .5 miles.

SCHOOL, the variable for public service, showed statistical significance, but did not have the expected sign. Instead, increased distance from a school by .5 miles increases home values by $9,126. This is more likely a model specification error. Instead of physical location of schools, the model would improve with quality of nearby schools. In this case, the added noise of students and traffic from buses could be seen as negative effects on home values and consumer would rather live slightly further away.

Both variables that measure amenities, REC and METRO, have negative coefficients and are significant. Each indicate a decrease in more than $10,000 with each .5 mile distance increase. The negative coefficients match the expected direction of the relationship.

WHITE and INCOME, the variables that measure socioeconomic characteristics, have positive coefficients and are statistically significant upholding current theory and matching the expected signs. As a community becomes more homogeneous, the home values increase, and as a community increases its median income, homes values also increase.

There are four variables for neighborhood design. DENSITY has a very small negative coefficient and is statistically significant. This is expected and can be interpreted as for every household added within a square mile, home values drop $2.85. This small amount aligns with the county's already dense nature, and therefore different densities within the county have negligible changes to home values. ROAD has the expected negative coefficient and are statistically significant. The coefficient indicates the greater the distance from major roads, the more it decreases a home's value. SHOP, similar to SCHOOL, has the opposite expected sign and is statistically significant. This suggests homes further away from shopping centers increase in home values. Referring back to Table 3, shopping centers are highly accessible. Shopping could share similar traits to roads, where having a center nearby is valued positivity, but being near a shopping center is undesirable due to traffic, loitering, and noise. NEARROAD has a large negative coefficient and has significance. Homes that are within 400 feet of major roads have a decrease in home values by over $27,000. The negative effect is as expected based on current theory.

Conclusion

The sign of the coefficient on the MIXED variable is important, since it indicates the effect of mixed land use zoning on housing values. A negative coefficient would have several implications. Since mixed land use is a relatively new development strategy, consumers may be unsure of the investment. Also, homes overall may be smaller and developments may lack single family homes. Both the uncertainty and lack of single homes contribute to possible decreases in home values.

NEARMIXED positive relationship better aligns with current literature, where Song's (2004) research already shows residential neighborhoods increase in home values when new types of property are added to the area. NEARMIXED's positive relationship with housing values supports that changing or adding new property types to existing residential areas can increase the value of those existing homes. The positive relationship also suggests that adding new mixed land use developments can increase values for homes not built within that development, but are located nearby.

The analysis shows full developments that zone homes as mixed land use may not have the positive effect that is currently perceived. There is a lack of evidence to support consumer’s belief that mixed land use adds value to their home. Without consumer demand, mixed land use will not increase the housing market, nor will the county see economic growth directly related to mixed land use. In contrast, homes within .5 miles may have an added value to their home. The homes could be in existing neighborhoods with alternative land types added to the area, or homes with new access to mixed land use developments.

It is important to note that there are doubts regarding the validity of this analysis. The model is limited to a relatively small geographic area and only a short amount of time has passed since the implementation of mixed land use. Analysis on a larger scale and observing changes over a longer time can contribute to estimating the economic impact of mixed land use. The data also does not distinguish different mixed land use patterns. Further analysis of homes near mixed land use and homes within mixed land use should include separating the types of mixed land use, and distinguishing entire development projects from additional land types built in developed areas. Separation and evaluation of each type will give more detailed conclusions than those reached with this paper. Additionally, several housing characteristics including number of bedrooms and bathrooms are not included. Therefore, the equation likely suffers from omitted variable bias. The choice to measure distance by intervals and setting the maximize distance at six miles is likely to effect the coefficient magnitude of the variables. Also, the dataset used in this analysis shows signs it is heteroskedastic.

The limitations are evidence that further research is needed to fully understand the effects of mixed land use on housing values. However, the analysis is most promising in implementing GIS as an asset for economic research. This research uses GIS tools that buffer and spatially join data points to create a majority of variables used within the regression model. Without the technology, it would be near impossible to create the measurable variables that the equation needed, especially due to the many observations that this dataset has. Each variable created through GIS added to the quality of the model and overall analysis of mixed land use. Expanding past regression analysis, the tools create visual aids to further understand physical design, demographics, and socioeconomic conditions. Visual representation alone expands the potential for future analysis through interpretation. Including GIS to estimate the housing demand function shows its importance as a method to create quantitative measures. An important contribution to this analysis, GIS has the potential to expand empirical analysis throughout the economic field.

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