Investigating Economic Development near the Interstate Highway System in the Washington D.C. Metropolitan Area using Spatial Methods

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Abstract

This paper attempts to investigate the relationship between the United States interstate highway system and economic growth within the Washington D.C. Metropolitan Area. Prior foundational research indicates that time series analyses common to this framework are prone to correlation errors. This research proposes analysis of the interaction using spatially explicit methods as an alternative means to mitigate the error types known to time series data. A map analysis is performed within ArcGIS by investigating patterns of developed land use type formation over the D.C. metro area. Land use change patterns are discussed with respect to influence from the proximate interstate highway system. Limitations of the spatially explicit model are differentiated from its non-spatial counterparts.

Introduction

Basic macroeconomic theory posits that any mutually beneficial exchange between two entities is a net gain in an economic sense. The premise of trade is founded on operational efficiency that creates positive wealth for the involved parties. The focus on trade has become the cornerstone of our capitalist society. Therefore, several means of enhancing trade have been developed to further this relative increase in wealth. The primary means of enhancing trade is to make it more accessible via transportation to increase the opportunity for interaction with respect to both ease and frequency of exchange.

The interstate highway system within the United States is one such system that is commonly credited with being a catalyst for trade and a subsequent increase in wealth. The relationship between interstate development and economic expansion is based on spatial analysis, but the interaction itself is fundamentally economic in nature. In this particular interaction, the economic development is the focal point of concern and can be considered a product of the interstate system.

Therefore, the interstate system takes on the role of the independent variable for this analysis. The performed research is an entry-level investigation on the visual relationship between the interstate highway system and generalized economic development using spatial modeling techniques as a means to bypass modeling errors typically associated with non-spatial methods. These errors will be discussed at length with regards to their impact on the results.

Literature Review

Due to the nature of economic expansion, a change of economic growth is the structural equivalent of a change in the standard of living on a per capita basis (Munnell, 1990). Within economic theory, there exists only two methods to increase the standard of living across any number of persons. The first method is to increase worker productivity within the set population. The difference in productivity for a worker over time is known as the marginal product of labor, and any increase in the marginal product of labor will foster a higher standard of living. The second method is simply to borrow wealth from elsewhere. However, since borrowing wealth by any means cannot foster sustainable economic growth over time, the first method is the primary choice for expansion (Krugman, 1994).

The interstate system is one of many theoretical sources for economic development. Rather than increasing the efficiency of a productive entity directly, the additional transportation option is able to make economically based products more accessible and easier to transport while enabling trade. This effect artificially inflates the marginal product of labor by cutting some of the cost of the products when they are purchased. The same product sold at a lower price in turn makes the population wealthier on a per capita basis (Munnell, 1990). The property of the interstate system functionally increasing the wealth of a population in turn encourages economic expansion, as the mutually beneficial interaction between a buyer and a seller becomes more accessible. It is this accessibility that stimulates investment and incentivizes growth spatially proximate to the transportation networks. This is the underlying theory of how transportation systems encourage economic development. The interstate system is simply one type of transportation system that fits within this theory.

Historically, this interaction is cited as the basis of several expansion sagas within human history. The most prominent of these is the European expansion from the 1300s and onward. Shipping and access to foreign lands around the Mediterranean Sea is often considered the basis for development and expansion for the European states. However, recent literature suggests that this effect is often

overstated in both objective and comparative analyses (Harlaftis, 2012). It is noted that European growth is robust, but no frame of reference is available to determine the marginal extent to which the transport system increased that growth. Re-stated, it is not possible to know if the accessibility via shipping is the basis of European economic development, and it is also not possible to know the extent of its influence. The transport network is only to be considered a possible explanation for historical growth and is no longer considered appropriate as a factor of causation. Comparative analyses have been made to China during similar time periods, and China's development is known to be comparable to Europe's despite a significant lack of external trade or shipping (Harlaftis, 2012).

In a modern context, the literature suggests that transportation systems are still the basis of economic growth. However, the caveat for this idea is that it is mostly based on shipping via air or by waterway. Studies from the last two decades generally hold to one of two similar outcomes when measuring the economic influence of the highway infrastructure. The first assertion is simply that the highway system is shown to have little to no impact on economic development, a finding that has been supported by a range of case studies predominantly dating from the early 1990s (Boarnet, 1995). This finding contradicts what is generally considered to be standard macroeconomic theory.

The second assertion is that the base theory itself is compromised because the change is measured at the margin rather than in summary to better determine the impact of the highways (Holtz-Eakin, 1992). The measurement is taken as a time series, in which the real outcome is measured and then set against a hypothetical projection in which all else is assumed equal but without the presence of the interstate highways. While this approach allows for the effects of the highways to be better understood, the modeling creates opportunity for estimation error within the alternative projection, as well as the subsequent result derived on the difference between the two. Therefore, while economic expansion near the interstate may be robust, it remains possible for a low amount of growth at the margin (Boarnet, 1995). In other words, the growth measured similarly in both the actual results and the

projection model, and little to no growth can be attributed to the variable presence of the interstate highways.

An unknown amount of error is also created from the base assumption of *ceteris paribus*, the concept of keeping all other conditions as static within the projection model. Due to economic measurements increasing in tandem with public infrastructure since World War II, time series data can show false positive correlations (Granger and Newbold, 1974). This effect is more pronounced in metropolitan areas, which tend to centralize both economic expansion and the infrastructure investment that is key to the development of the interstate system. Therefore, the regression analysis based upon the time series carries the implication of naturally favoring a strong correlation in the result where little to no actual relationship is present (Granger and Newbold, 1974).

Statistical tests for inaccurate correlations have been applied to a limited number of these case studies in an attempt to adjust for the correlation errors. When the appropriate corrections were applied, the production function showed little to no relation between highway infrastructure and private sector output and productivity (Tatom, 1991). This result was found similarly in other adjusted regressions, such as Kelejian and Robinson (1994) and Aaron (1990). The latter study also concluded that time series data can be sensitive to a small number of influential observations. This suggests that the time series models are an unreliable method for testing economic expansion, and that focusing on the temporal aspect of expansion may lead to misleading results (Aaron, 1990).

Two types of modeling error exist within the analysis due to the nature of the relationship being observed. The first problem is that any measure of economic expansion or productivity has implicit potential for output spillover from other forms of infrastructure investment (Munnell, 1992). This is in part due to model premises that are not easily adjusted; the hypothetical basis of this problem is that these models refer to public infrastructure as the independent variable and the difference in economic productivity as the dependent variable when calculating correlation. This allows for the formation of

economic development coincidental to highway development rather than being directly associated with it (Munnell, 1992). In other words, the economic development may be due to other forms of infrastructure nearby but independent of the highway system.

The second spatially explicit issue operates within the economic context of the margin. Observed marginal growth may also be false even after a correlation adjustment. This is because the interstate highway may act as a centralizing landscape feature by simply moving development areas to a proximate range of the highway (Munnell and Cook, 1990). This implies that the development would have occurred with or without the existence of the interstate system. Instead, that development or change in productivity was simply moved and would therefore be noted as expansion caused by the interstate (Garcia-Mila and McGuire, 1992). In effect, a spatially explicit type 1 error is created, as there is no relationship present between that particular economic development and the nearby highway. The productivity level was not altered and only the location of the development has any noted change.

Some of the error related to modeling techniques do not have simplistic solutions in terms of forming a more accurate relationship between highways and economic growth with the spatial aspects of the highway-based expansion. However, the statistical inaccuracies formed in the temporal-based time series models may be avoided by changing the modeling approach (Boarnet, 1995). In order to prevent the spurious projection and correlation errors shown in the time series models, a spatially explicit modeling approach may be better suited to this type of analysis.

Rather than comparing actual rates of change against their projected counterparts, it may be more effective to measure the observed land use change patterns within proximate distance of the highway system against the land use change patterns over the total study area. This should allow for a visual differentiation analysis of the marginal effects of the interstate highways by focusing less on the temporal aspect. However, this modeling approach has its own limitations and difficulties, which are discussed later within the analysis.

Study Area

This study was performed for the Washington D.C. Metropolitan Area. As defined by the 2010 United States Census, this area is comprised of the District of Colombia, as well as several surrounding counties within Virginia, Maryland, and West Virginia (US Census Bureau, 2011) (Figure 1). The counties are further discerned into layers based on their proximity to Washington D.C. While the study may have differing relevance to each of these layers due to the spatially heterogeneous nature of economic development, the entire metropolitan area was included for the analysis in order to be consistent with the current definition of the area.

Washington Metro Area Jurisdictions

Core: District of Columbia, Arlington, Alexandria

Inner Suburbs: Montgomery, Prince George's, Fairfax (including cities)

Outer Suburbs: Frederick, Loudoun, Prince William (including cities)

Far Flung Suburbs: Calvert, Charles, Clarke, Fauquier, Fredericksburg, Spotsylvania, Stafford, Warren, Jefferson

Figure 1. The DC Metro Area county list (US Census Bureau, 2011).

As the national capital of the United States, Washington D.C. and its surrounding areas have received an accelerated rate of economic and population growth. However, as intrinsically tied as the metro area is to government operation, proper measurement of wealth is precariously judged with relation to the residents within the study area (George Mason University, 2011). While some of the growth of the metro area is certainly due to true development, some portion is also due to government expansion. It is not currently known to what extent the study area has experienced each portion. Economic expansion and population for this area are therefore likely to be artificially inflated (Voss and Guangqing, 2006).

Spatial Methods

The method for this study was designed to investigate the relationship between economically based development and proximity to the interstate system. The model follows the theory outlined prior under the basis that it is the proximity and subsequent accessibility to the transport network that fosters the economic growth. Therefore, economic expansion has been modeled with two differing ranges of proximity to the interstate roads within the study area, and the results are used for comparative analyses to determine the nature of the relationship. Due to limitations within data accessibility, land cover data from 1984, 1992, and 2001 were taken as base years and used for this analysis. These data sets were chosen to refer the temporal component of the analysis to be as nearly decadal as possible in structure.

To appropriately measure the effect of the changes, the processing and analysis of the area was performed using ArcGIS software to produce visual output maps. The Washington D.C. Metropolitan area was first selected to be consistent with the definition outlined by the US Census. Additionally, the definition chosen for the study area is based off of the current definition and not those of the data set years to maintain a consistent area of study. The DC Metro Area was identified and selected in ArcGIS and exported as its own shapefile. The United States roads were also accessed but required differentiation for both type to identify the interstate system and for proximity to the study area. The roads were clipped to match the DC Metro Area and all others were removed. The remaining roads were then selected by attribute to differentiate the interstate roads from all others. As per the technical definition provided by the U.S. Census Bureau, the roads were selected by the MTFCC code labeled for interstate highway roads (Department of Commerce, 2012). These roads were then exported as a shapefile. Finally, land cover data for 1984, 1992, and 2001 were clipped to match the DC Metro Area. The land cover types were reclassified based on the Anderson Level 1 classification system, in which all developed land types were given a set value and all other land types were set to No Data. The purpose

of the reclassification is to designate areas of growth to allow, as developed land use type is representative of economic expansion. The clipped, reclassified land use data was then exported as a shapefile. In this way, the DC Metro Area, its interstate highway roads, and developed land were prepared for the processing and analysis (see figure 2, page 11).

A distance grid was established as a means to measure proximate distance from the interstate roads within the study area. Two raster buffer zones were established using the Euclidian Distance function, set to 0.5 and 1.0 miles away from the interstate roads. No prior method of comparison was available from the literature, as economic models of growth from interstate growth tend to be framed with respect to finances rather than spatial distribution. Therefore, the distances for the buffer zones are arbitrary set under the premise of proximity with regard to the basic theory mentioned prior.

Land cover change patterns were then derived from the remaining land cover data within the buffer zones by using the Combine function. The resulting output rasters showed new areas of development within the buffer zones for each of the base years. Using the Subtract function, new output grids were created by subtracting the 1992 data from the 2001 data for each buffer zone. This process was repeated again, subtracting the 1984 data from the 1992 data. This resulted in a total of 4 output grids showing the difference in development between each time period, one with buffers and one without for each time interval (see Figures 3, 4, 5, and 6). These outputs grids collectively show new growth that had not existed in the prior time intervals both with and without buffers to allow for comparative analysis within land use change patterns. The completed grids showing new urban development land is the basis for the comparative spatial analysis for economic growth.

Spatial Analysis

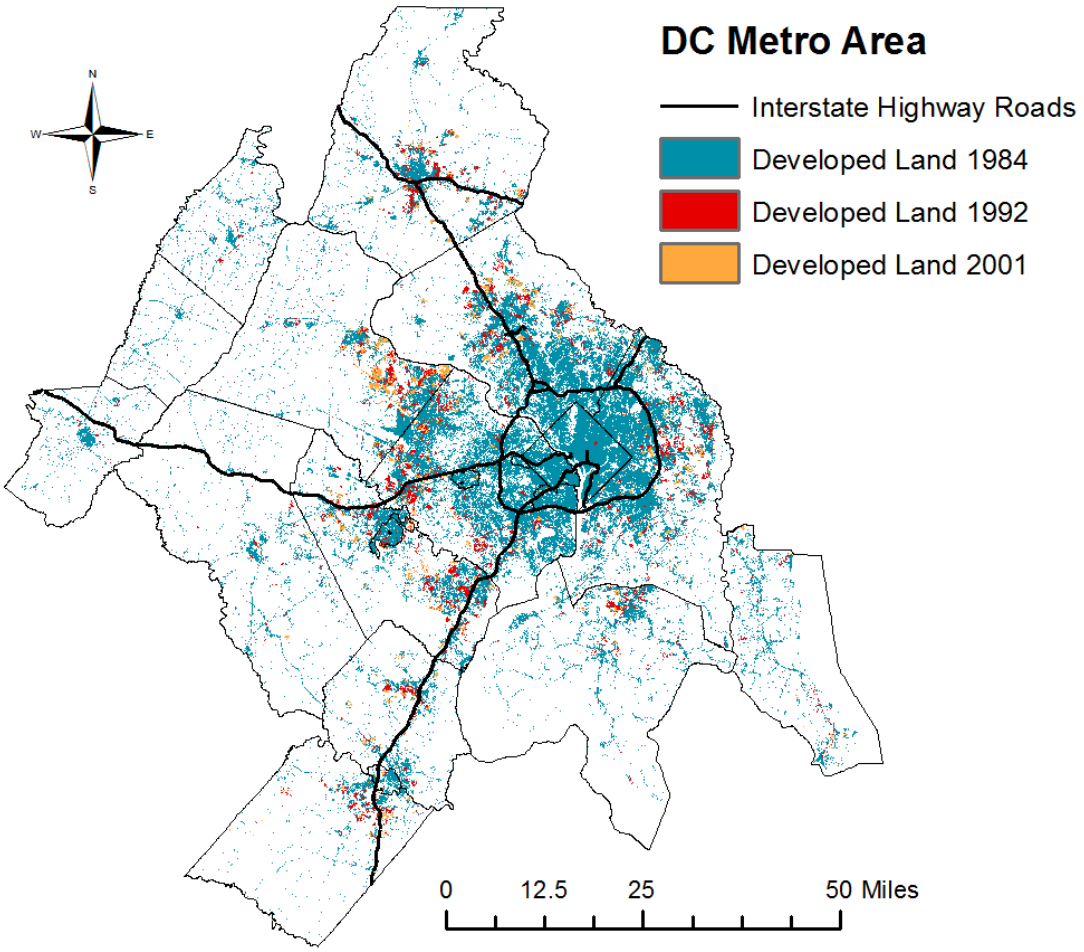
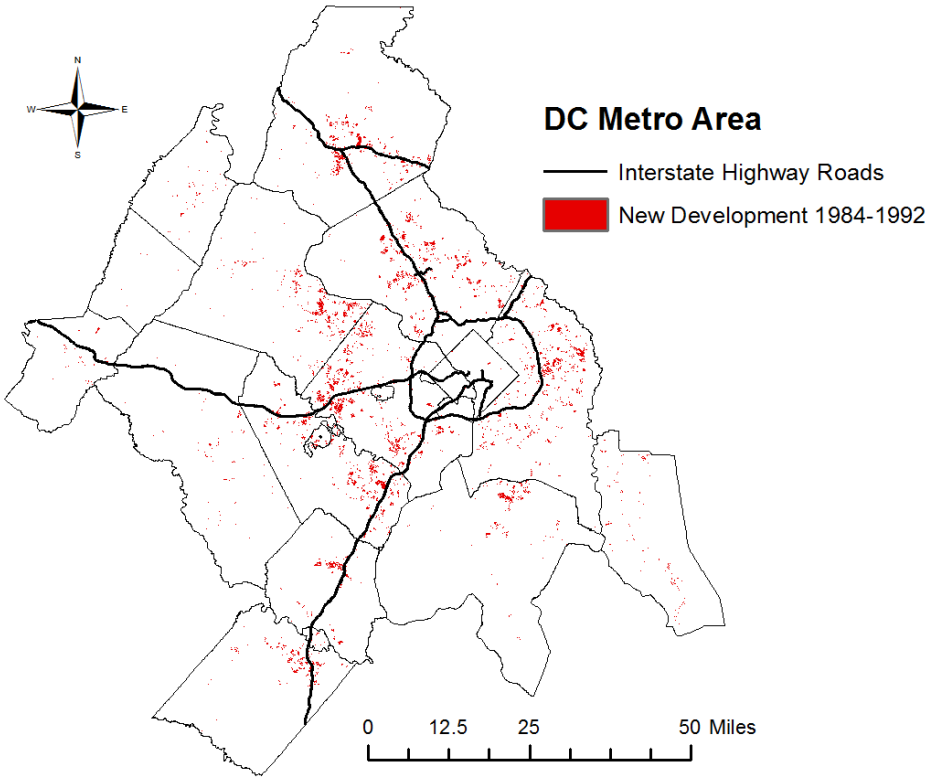
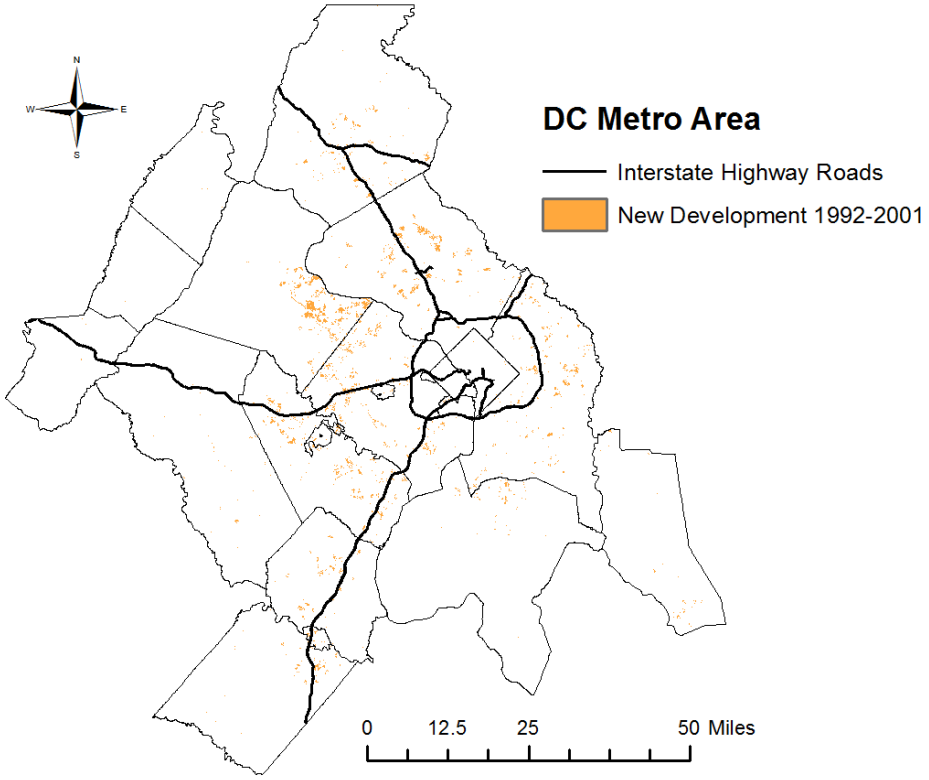


Figure 2. Base development conditions by year, differentiated by color to show growth rates.

As expected within a metropolitan area, the developed area expansion is centralized geographically toward areas of prior development. This is evident for the District of Colombia, but the trend also holds for smaller cities within the study area, particularly Frederick, Maryland, Manassas, Virginia, and Stafford Virginia. The purpose of the initial map of development (above) is to provide a point of reference for comparative analysis. The initial development from the base year 1984 is shown in dark teal, new developments from the 1984 to 1992 period are shown in red, and new developments from the 1992 to 2001 period are shown in yellow. The actual change conditions when isolated shown as only new developments are fairly sparse, as can be seen below.





Figures 3 and 4. New development can be seen in the land cover data within the metro area. However, there is no accentuated increase in development rates near the interstate.

These maps indicate that the spatial distribution of growth is clustered around other areas of prior development. In particular, the highest rates of growth from 1984 to 1992 can be seen in a radial pattern around Washington D.C. in every direction except the southeast. This is consistent with the locations of developed land use in the base year of 1984, which maintains a similar radial pattern with regards to land that has already been developed at that time. In the second time interval of 1992 to 2001, the majority of this expansion has slowed considerably, as represented by the lower quantity of colored material when compared to the prior map. During this time, most of the development within the metro area is shown to be centralized around Leesburg, Virginia. These results must then be compared to the growth proximate to the interstate highway system.

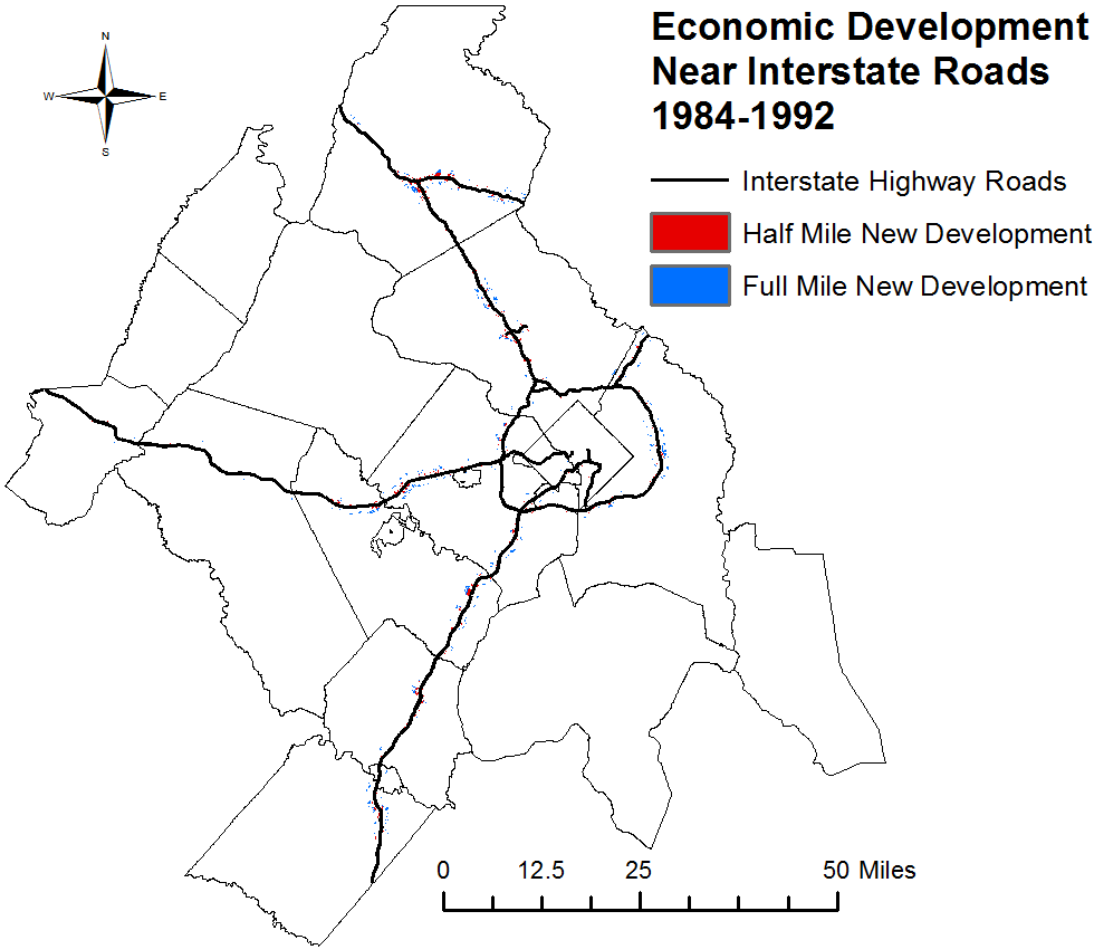
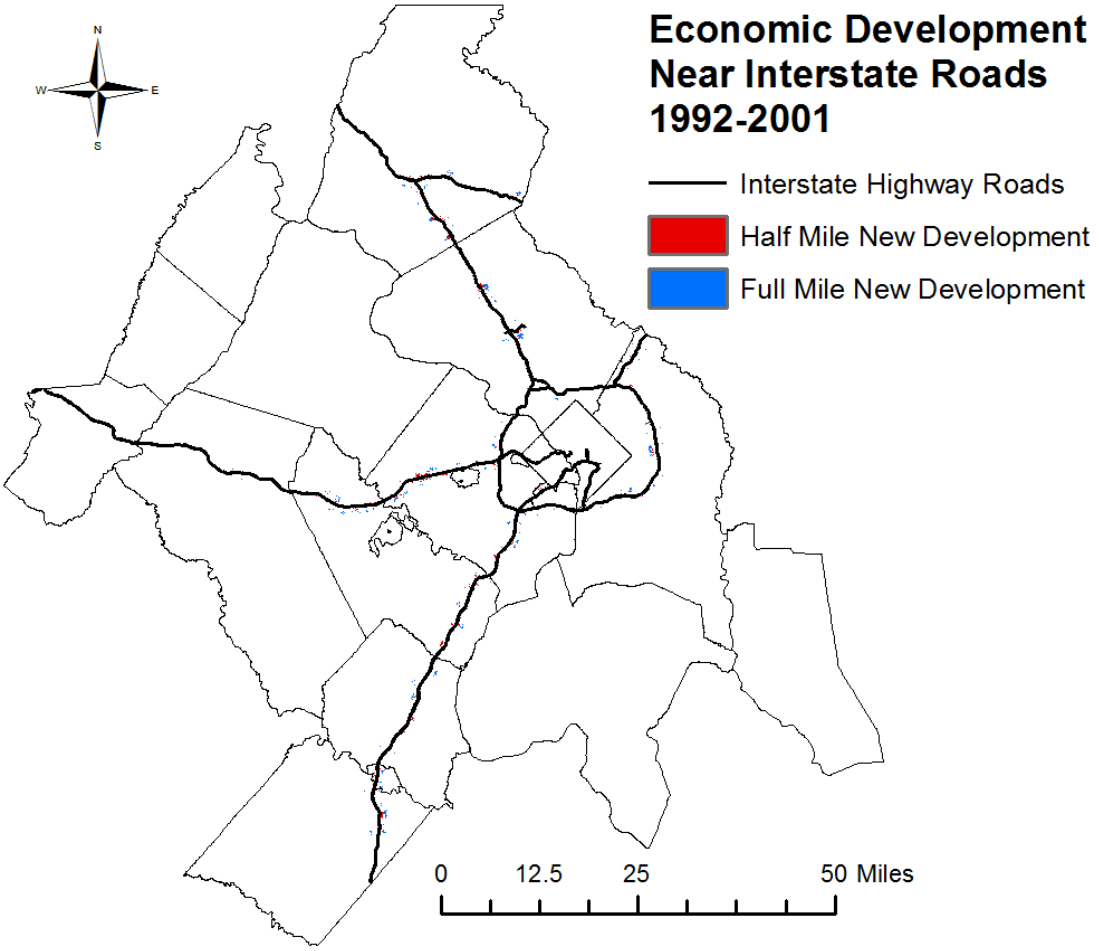


Figure 5 (above) and 6 (Page 14). While the growth near the highways are visually sparse, these areas also constitute a significantly smaller fraction of the study area.



Growth shown within the buffer areas seems to vary between the two time intervals. During the 1984 to 1992 time interval, the case for highway based growth is stronger, as notable areas of new development can be seen along interstate lines. The areas with the most development appear to be near Frederick, Maryland and along the I-66 corridor to the west of Washington D.C. Perhaps most interesting, the majority of growth lies within the second buffer, which covers the 0.5 mile to 1 mile range away from the interstate. During the 1992 to 2001 time interval, new growth along the interstate roads has diminished considerably, a trend that matches the development rates of the remainder of the study area from Figure 4. This in turn weakens the observed relationship between interstate roads and economic development. Instead, the growth pattern seems to favor the prevailing economic climate of the region in tandem with other areas of centralized development.

Discussion

The results of the analysis match those found in the foundational literate on both the observational and implicit fronts. First, the early literature from the 1990s suggests that the economic effect from the highway infrastructural is overstated and shows little support for the macroeconomic theory that it is premised upon. The findings in the spatial analyses match these findings, suggesting that the interstate highways have little to no effect on development. In the 1984 to 1992 observations, there appears to be no visible relationship, and the areas of recent growth show no real influence from the region's interstate highways. In the 1992 to 2001 observations, the majority of growth is visibly concentrated toward areas that are not proximate to the highway roads. This second set of observations suggests an inverse relationship and that development favors distance from the highway roads. The notion that highway presence hinders development likely has no basis, but instead reinforces the literature in that the two are poorly related.

Secondly and on a modeling level, the results of the spatial model oppose those of the time series models from other metropolitan areas. Since the spatial model uses only observations and no projections, it may be a fair assertion that the time series modeling does in fact create type 1 errors in its correlations. The basic spatial model used for this may help discern the bias introduced by non-spatial modeling techniques. It is important to note that the comparison between models offers only one possible point of concern and does not necessarily offer any causation factors at this time.

It is important to note that the spatial model does has no method to resolve potential sources of spatial error noted within the time series studies. Therefore, no corrective methodology can be offered with respect to possible spillover issues or false margin from relocation. However, the lack of a centralizing pattern of growth to the highway roads may translate into these effects being negligible, as these errors fundamentally require a centralizing pattern of development to exist. More refined models must be formulated before this concern can be confirmed as valid.

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