Analysis of Firm Location and Relocation
Around Maryland and Washington, DC Metro Rail Stations

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Abstract

Transit Oriented Development (TOD) is commonly adopted in regional transit plans as a tool to achieve economic growth, sustainable land use patterns, and pedestrian-friendly communities. Some critics, however, have questioned TOD as an agent for net job creation. While some research has used case studies and agglomerated regional datasets to examine changes in employment near transit with positive results, there is a paucity of literature examining the relationship between rail stations and employment by industry at the transit station level.

This is a descriptive study that seeks to address three key questions about the effects of station proximity: 1) What is the overall distribution of firms in relation to metro station locations? 2) What industries, if any, are more likely to locate near transit stations? 3) Does a new transit station result in a net gain of firms within the station proximity and for the region or does it merely redistribute existing firms? This study applies GISs to examine the National Establishment Time Series (NETS) dataset within the region comprising Washington DC, Montgomery, and Prince George’s Counties in Maryland. The NETS dataset contains longitudinal and cross-sectional firm-level data for the years 1990 - 2010, which allow us to look at changes in the number of firms within relatively small geographic areas around Metro stations, several of which were constructed during the 21-year period. The NETS dataset also provides firm-level relocation information for the same time period to assess firm movement within and outside of the study area as they relate to transit stations.

First, we identify firms within station buffers and conduct a location quotient analysis. Second, we conduct a spatial analysis of firm locations over time, applying choropleth maps, descriptive spatial statistics, and hot spots analysis. Third, we plan to apply a space-time cluster analysis that visualizes the distribution of spatial-temporal data, taking into account the time dimension, and enables us to identify clusters of events constrained by both space and time. Finally, using NETS firm relocation data for the period of 1990 to 2010, we conduct an analysis of firm locations before and after each relocation. The analysis is conducted for all industries as a group and a few specific industries that show a strong presence in the region, including finance, insurance, and real estate (FIRE) industries, which have been found to predominate in dense economic centers.

This study contributes to the literature on the effect of transit investment and TOD on economic development, particularly addressing the question of net effects for locations beyond the immediate station area, which is an important implication from a regional planning perspective.

Key words: firm location and relocation, GIS, National Establishment Time Series data (NETS), transit-oriented-development (TOD), spatial-temporal data
1. INTRODUCTION

The Washington DC metropolitan region has been growing and will continue growing into the future in terms of both population and jobs. According to the Metro Washington Council of Governments (MWCOG), the region’s population will add at least another 2 million residents by 2050, while its employment will increase from 4.01 million in 2040 to 5.56 million in 2040. These forecasted numbers pose many challenges about accessibility, sustainability, prosperity, and livability to this National Capital region that encompasses the District of Columbia, Maryland, and Virginia, including issues related to economic development, environment, housing, transportation, and social equity (Coalition for Smarter Growth, 2010). In order to address these challenges, MWCOG formed the Greater Washington 2050 Coalition in 2008 to gather opinions and concerns of public, business, civic and environmental stakeholders and identify actions with a consensus for the future. Within its nine major sets of goals, the Region Forward planning initiative includes economic prosperity and the integration of land use and transportation, emphasizing a wide range of employment opportunities, balanced growth across the region, and compact infill development with mixed land use, among others. This vision leads to an identification of regional activity centers for the focus of future growth, as they will likely capture new employment and household growth in the future. Many of these activity centers include rail transit stations, recognizing the important role of transit access, transit investments, and TOD.

Similarly, a few organizations in the region propose to use access through public transit service to stimulate economic development and form employment centers (Coalition for Smarter Growth 2010; The Central Maryland Transportation Alliance and the Center for Transit-Oriented Development, 2009). Thus, there are many regional plans and studies in which transit oriented development (TOD) is touted as a catalyst to integrate transportation and land use, promote transit and pedestrian travels, provide a good mixture of commercial and residential neighborhoods, increase property values, help local economic development, and create livable communities. However, while a few studies found that rail transit proximity and TOD are associated with a higher concentration of firms and employment in professional/high-skilled jobs and particular industries, such as finance, insurance, and real estate (FIRE), these claims need more evidence based on solid empirical research. In addition, some critics have questioned TOD as an agent for net job creation (Giuliano 2004; Giuliano and Agawal 2010). While some research has used case studies and agglomerated regional datasets to examine changes in employment near transit with positive results (Cervero, 2004; Belzer, et al., 2011), there is a paucity of literature examining the relationship between rail stations and employment by industry at the transit station level.

In this paper, we conduct a descriptive study that seeks to address three key questions about the effects of station proximity:

1) What is the overall distribution of firms in relation to metro station locations?
2) What industries, if any, are more likely to locate near transit stations?
3) Does a new transit station result in a net gain of firms within the station proximity and for the region or does it merely redistribute existing firms?

Following this introduction, the next section provides a review of the relevant literature on TOD, firm location, and the economic development effects of rail stations. After descriptions of the data, data processing, and methodology used, we present analysis results. The paper
concludes with a summary of analysis findings, planning and policy implications, and future research agendas.

2. LITERATURE REVIEW

Public transportation investments could have substantial impacts on the distribution of firm and employment locations, land development, and property values by changing the level of accessibility (often measured by travel time) among locations. The concept of using a transit facility as a node for development is well known as transit oriented development (TOD). Transit Oriented Development (TOD) is commonly adopted in regional transit plans as a tool to achieve economic growth, sustainable land use patterns, and pedestrian-friendly communities (Cervero, 1989; Calthorpe, 1993).

While many studies examine the economic impacts of rail station presence and proximity, rail transit investments, and Transit Oriented Development (TOD), most studies address the effects on values or rents of residential and commercial properties. A few studies found that light and heavy rails have a positive effect on commercial and office properties (Weinberger 2001; Cervero and Duncan 2002; Ko and Cao 2012), while there is an increasing number of studies that show a positive effect on residential property values (Ryan 1999; Hess and Almeida 2007; Debrezion, Pels, and Rietveld 2011; Duncan 2011). Even when transit access is capitalized into property values, its effect seems to dissipate over distance; Ko and Cao (2012) found 0.9 miles from rail stations as the distance at which the effects on non-residential property values becomes insignificant.

An increase in land values leads to a need for higher-density development, which often requires land use changes. In this regard, the literature is inconclusive; while several studies indicated land use intensification in relation to rail transit and related positive economic effects (Landis and Cervero 1997; Cervero et al 2004; Arrington and Cervero 2008), other studies showed little evidence for significant land use changes in the cases of light rail in Portland, Oregon over a ten year span (Dueker 1999) and in Buffalo, New York (Banister and Berechman 2000). Because of these mixed results, Giuliano (2004) and Giuliano and Agarwal (2010) argue that transit investment is not effective to influence land patterns, partly because the magnitude of transit investment is still marginal within the large transportation system already developed in a metropolitan area. In contrast to the extensive research on the impacts on property values and land use patterns, the current literature on transit investment and TOD lacks empirical studies on the effects on the location, densification, and distribution of firms, as well as employment, especially taking into account multiple types of industry.

The literature on firm location points out the importance of accessibility through transportation infrastructure is important for firm location decisions. Among many factors that can influence firm location decisions within an urban area or a metropolitan area (e.g., between a central business district vs suburbs, and a specific location within these areas), economic theory tells us that transportation costs of inputs and outputs and agglomeration economies, along with differences in factor costs (rent, taxes, and labor costs) are more important than political factors and amenities that influence the quality of life (Clapp 1993). Starting with factor costs, cost of space is considered as one of most important firm considerations (Button et al, 1995; Calzonetti and Walker, 1991). Availability and lower cost of space has helped spur suburbanization of businesses (Leinberger and Lockwood, 1986; White, Binkley, and Osterman, 1993). Taxes and costs associated with transactions (e.g., building permits) are also important in deciding firm
locations where choice are among multiple jurisdictions with different taxes, laws, and regulations (Parsons Brinkerhoff, 1998).

Transportation access affects firms’ costs of doing business because firms need access to materials, workers, customers, and information. Transportation has the ability to increase employment or firm density through increased access to labor and better links between companies (Venables, 2007). In particular, public transport investments potentially play an important role for the spatial densification within the proximity of transit network nodes, as some firms take an advantage of travel time savings provided by good transit access in their location decision making (Chatman and Noland 2011). Traditionally firms seeking highly skilled workers located in CBDs to have access to the widest pool, but suburbanization has led some firms to realize that they can find adequate labor in the suburbs, especially educated clerical workers, professional and technical workers (Ihlanfeldt and Raper, 1990; Hanson and Pratt, 1989). Access to highways is one of most important firm location factors, as automobiles are the dominant form of transportation in most urbanized areas (Lyne, 1988; Button et al, 1995; Calzonetti and Walker, 1991, Cervero and Duncan 2002; Ryan 2005). As the level of accessibility through the road network could vary depending on traffic and congestion, transit networks with exclusive uses, such as rails and bus rapid transit (BRT), may have advantages in congested urban areas (Forkenbrock and Foster, 1996).

Agglomeration economies may benefits firms through the following mechanisms (Chatman and Norland 2011):

1) sharing consumer-side service, retail, and entertainment amenities “increasing the city size or the CBD size enabling the provision of urban amenities that are attractive to households.” (by enabling city growth and densification);
2) sharing/matching pools of labor (enabling better matching of workers to jobs; less turnover);
3) matching firms in disaggregated production processes (enabling vertical disaggregation and supplier specialization);
4) learning innovative practices (i.e. knowledge spillovers) (skilled labor learning from each other; quick dissemination of innovative practices);
5) sharing production inputs; and
6) sharing transport infrastructure.

Densification and balance of commercial and residential land use around rail stations throughout the network will increase local and regional accessibility. In addition to high-density development associated with higher property values based on good accessibility, a significant level of mass transit service, such as metro services, can improve accessibility to and from workplaces, eliminate of the need of more roadways and large parking lots, and enable higher proportion of land developed for economic activities.

It is unlikely that information sharing in knowledge spillovers occurs beyond walking distances, even in higher density areas near stations because of likely dependence on the intensity of development near selected stations (Chatman and Norland 2011). There has not been much research in the past that explicitly examines the effect of public transportation on agglomeration and economic productivity, resulting in a lack of clear evidence for any of the mechanisms listed above (Chatman and Norland 2011).

Among a few studies on the subject, Zimbabwe and Anderson (2011), based on the review of
previous work on the subject, suggested that some jobs are more transit oriented than others, including professional, scientific and technical services, and the finance and investment industries. Belzer, Srivastata, and Austin (2011), in their study commissioned by Center for Transit Oriented Development (CTOD), examined the compositions of industry sectors of employment within a half-mile from transit stops, using Census Longitudinal Employment-Housing Dynamics (LEHD) data for 19 urban areas with fixed-guideway transit service. Their main findings include: (1) a higher job density near transit stops, (2) a net increase in employment near transit over seven years, (3) a higher likelihood to be located near transit by the sectors of public administration, knowledge based industries (information, finance and insurance, real estate, professional, scientific, and technical services, management as a group), retail, and production, distribution and repair, and (4) a general trend of an increase in the number of jobs in the knowledge based industry near transit. Although the study findings are indicative, an unclear description of an analytical method to aggregate data from the 19 urban areas as one data set leaves room for questions. Mejia-Dorantes et al (2012) applied spatial statistical techniques to a micro-level data in order to evaluate the effects of Madrid’s metro line expansion on business location patterns by different industry sectors. Their study results provide evidence for the effects of urban accessibility through transit infrastructure on the pattern of economic activity location, in which agglomeration plays an important role.

Overall, while an analysis of agglomeration has been done in a regional scale and a variety of studies on TOD can be found, little research has been done to examine the relationship between the distribution of firms and jobs in relation to rail station presence and proximity.

3. DATA AND DATA PROCESSING

The main data set that this study examines is Dun and Bradstreet’s National Establishment Time Series (NETS) dataset within the region comprising Washington DC and Maryland. NETS data include information for the locations of firms by the latitudinal and longitudinal coordinates, the North American Industry Classification System (NAICS) codes, total employment, total sales, sales growth trends, and the times of firms’ relocation. The NETS dataset contains a rich longitudinal dataset of firms in all industries that existed in the District of Columbia or Maryland at least at one point during the 21-year period from 1990 to 2010: a total of 148,464 records and 869,574 records in the District of Columbia and Maryland, respectively (the main dataset). It also provides a dataset of firms that relocated for the period 1991 to 2010, specifying the origin and destination of the relocation with county codes and the latitudinal and longitudinal coordinates (the relocation dataset). NETS data were imported into ArcGIS and processed in order to identify geographic locations of firm observations in the data set, and then the firm level (point) data were aggregated into several geographic levels, including census blocks, census tracts, and half-mile buffers around Metro stations.

The use of the NETS data requires some caution due to its nature and structure. First, the original format of the NETS database is convenient for examining the most current year’s firm data, but not for historical trends, as it only provides geographic coordinates for the firms’ most recent location. The dataset lists firms in each year from 1991 to 2010, regardless of whether

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1 A series of reports by Center for Transit Oriented Development (CTOD) discuss employment concentration and location, development patterns, value capture and agglomeration of high-skilled/knowledge-based occupations in the context of TOD (Belzer, Srivastata, and Austin 2011; Fogerty et al. 2008; Forgerty and Austin 2011; Gorewitz and Evanston 2006).
they were actually located in the area of study at that time. For example, the dataset could contain data of Firm A from 1991 to 2010, although it was located in the study area only between 1998 and 2006. In regard to employment data, this means that an attempt to sum the number of employees for a given year prior to 2010 in a specified station area would include employees of firms that have moved outside of that area or have not yet moved into that area. In order to eliminate such firm records, the relocation dataset was appended to the main dataset to determine which years a firm that had relocated was located in the study area. In order to append the relocation data, the wide-format of the main dataset was transformed to a long-format, such that there is a row for each firm-year record. This long-format is also the format needed to conduct spatial temporal analysis.

Second, there is a varying degree of precision in the geocoding of firms location in the NETS dataset. The firm location coordinates are geocoded based on five different levels of precision—block face, block group, census tract centroid, zip code centroid, and street level. While the majority of data are geocoded with block face-level precision, which uses the roof top of the building as the location, approximately 12 percent of the firms’ locations are plotted using the zip code centroid. This is the least precise level of geocoding, which may lead to some concerns about the accuracy of the location.

We created two types of buffers to identify firms within the proximity of WMATA Metro station proximity. We used a walking distance of 0.5 miles on the street network, as opposed to a simple Euclidean distance to determine “station buffers.” The use of the street network distance is particularly important to our study because many of the suburban Metro Stations in the study area have large commuter parking lots and sparse road networks. In addition to creating the individual station buffers, a merged station buffer that contains all of the area collectively within the individual station areas was created for parts of the analysis. Because of the overlap between station buffers—especially in downtown Washington DC—the merged buffer provides more accurate totals for the number of firms within the combined station areas than simply summing the individual station numbers. There will necessarily be firms that are double-counted or triple-counted when looking at the figures for individual buffers because of the close proximity of Metro Stations to one another downtown.

One caveat from the data point view in this study is that our dataset did not include the Virginia NETS dataset due to limited resources, and that only Metro Stations in Washington, DC and Maryland are considered in our analysis of firm location. In this paper, our main study area is set as the combination of the District of Columbia and two counties in Maryland—Montgomery County and Prince George’s County (Figure 1).
4. METHODOLOGY

In this study, we employ a series of statistical, economic, and spatial analysis methods to examine NETS data in order to describe the distribution of firms of various industries: (1) across the DC metro region and (2) in relation to WMATA Metro stations. First, we conduct an analysis of location quotients (LQs) to identify industries with a strong presence around the metro stations. Then we conduct a trend analysis of the number of firms in the five industries outside and within the station areas, including one by firm size for the FIRE industries.

We conduct a spatial analysis of LQ values for the FIRE industries within the individual
metro station areas, using the 2010 data. Further spatial analysis techniques, such as choropleth maps of firm density, spatial central mean and directional distribution, and cluster analysis using Getis-Ord Gi* statistics, are used to describe the distribution of firms across the study area over years. Then spatial-temporal analysis techniques are used to visualize the firm growth distribution not only across space, but also over time.

In the last part of the analysis, we analyze the firm-level relocation data for the period from 1991 to 2010 to assess the level of firm movement within, into, and out of the aggregated station buffer area and the study area. To analyze the origins and destinations of firms at an aggregated level, four mutually exclusive geographic areas are defined: 1) the aggregated station buffer, 2) the MWCOG planning area, 3) Maryland exclusive of the MWCOG planning area, and 4) and all locations external to Maryland and the Virginia portion of the MWCOG planning area. From which of the four geographic areas the firm originated (origin) and to which category the firm moved (destination) are determined based on their mapped locations. Data of those that fall within the aggregated station buffer are examined to count the numbers of arrivals from and departures to each of the four categories.

5. ANALYSIS RESULTS

Analysis of Industries in the DC Region from 1990 to 2010, using Location Quotients

As part of determining which industries should be investigated at a higher level of detail, a location quotient analysis was conducted for all two digit NAICS codes. This analysis showed that professional services, FIRE, and food and accommodations were all represented more highly within station areas. Conversely, agriculture, manufacturing and mining were all under-represented within the station areas. A table of this analysis is shown in Appendix A.

Analysis of Industries with a Strong Presence in the DC Region from 1990 to 2010, using Location Quotients

Table 1 shows location quotients (LQs) of the five selected industries outside and within the metro station areas from 1990 to 2010 with a five-year increment. For the FIRE industries, values outside the station areas have remained relatively consistent over time. In contrast, more variation can be found when examining this industry category within the station areas, as values have ranged from 1.06 to 1.14. Professional services’ LQs are much higher within the station areas than outside the station areas; for example, the LQ value within station areas was 1.34 in 2010, compared to 0.90 outside of the station areas. This indicates that professional services jobs within the region are more likely to locate within the station areas than outside.

The healthcare and arts and entertainment industries show relatively close LQ values within and outside the station areas; both industries increased LQ values within the station areas after 1995 to become higher than 1.0 in 2010, indicating their gradual increasing presence in the proximity of stations. Lastly, food and accommodation firms have seen the greatest proportional growth in LQs, increasing from 1.21 in 1990 to 1.47 in 2010. Moreover, the LQ values outside the station areas for this industry show a slight decrease in the same period, indicating that more firms in this industry are choosing to locate near station areas.
Table 1 Location Quotients of the Five Selected Industries outside and within the WMATA Metro Station Areas

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<td>Professional Services</td>
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<td>0.99</td>
<td>0.97</td>
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<tr>
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<td>1.05</td>
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<tr>
<td>Food and Accommodation</td>
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<td>1.08</td>
<td>1.13</td>
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<tr>
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<td>1.24</td>
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<td>Arts and Entertainment</td>
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<tr>
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<td>1.32</td>
<td>1.47</td>
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Trends in the Number of Firms by Industry from 1990 to 2010 in the DC Region

The total number of firms within the study area has increased substantially from 1990 to 2010, representing a growth of 131 percent. Within the study area, professional services firms grew the most, with an increase of 164 percent over the 21 year period, while the FIRE industry also grew substantially, almost doubling the number of total firms (Figure 2). Firms in the professional services industry that are located outside the station areas experienced fairly consistent rapid growth (Figure 2(a)) compared to those within the station areas, which show more variation. FIRE firms grew substantially faster outside the station areas (139 percent) than within the station buffers (59 percent). All of the five industries show faster growth outside the station areas than within.

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Figure 2 shows the number of firms by industry that were found (a) outside of and (b) within the station areas during the study period. Within the study area, professional services firms grew the most, with an increase of 164 percent over the 21 year period, while the FIRE industry also grew substantially, almost doubling the number of total firms (Figure 2). Firms in the professional services industry that are located outside the station areas experienced fairly consistent rapid growth (Figure 2(a)) compared to those within the station areas, which show more variation. FIRE firms grew substantially faster outside the station areas (139 percent) than within the station buffers (59 percent). All of the five industries show faster growth outside the station areas than within.
Firms of different sizes have different needs in space and often have different impacts relating to their economic impact on regional economics. Figure 3 shows the number of FIRE firms by the employment size category (a) outside and (b) within the station areas. Firms are grouped into four categories of sole proprietors (1 employee), small (2-10 employees), medium (11-50 employees) and large (more than 50 employees). Small firms had the most substantial growth both within and outside the station areas in the 21 year period—by 132 percent and 70 percent, respectively (Figure 3 (a) & (b)). Their growth shares a similar trend line in both graphs, although it is more pronounced outside the station areas. In Figure 3 (a), sole proprietors outpaced growth of medium sized firms outside the station areas, growing by 426 percent.
Medium-sized firms outnumbered those with only one employee during the early part of the study area, but saw slow growth during the rest of the period. Within the station areas, the number of sole proprietors increased, but not as much as the medium-sized firms, representing 227 percent and 23 percent, respectively (Figure 3 (b)). In both geographies, large firm growth was relatively stagnant over time, increasing by only 10 percent outside of station areas and 13 percent within station areas between 1990 and 2010. It is important to note that while large firms may not have increased during this time period, they could be adding employment.

**Figure 3 The Number of FIRE firms by Number of Employees (a) outside and (b) within the Station Area**

(a) Outside Station Areas

(b) Within Station Areas
Figure 4 shows the LQ values of the FIRE industry category in individual station areas in 2010. Station areas with high LQ values in these industries are spread throughout the WMATA Metro service area. While there are station areas with LQ values higher than 1.00 on all of the metro lines, a concentration of high LQ station areas can be seen along the western portion of the Red line with Bethesda, Friendship Heights, Twinbrook, and White Flint. Low LQ values are also distributed within the study area. The Anacostia, Brookland and Waterfront stations within Washington DC, Forest Glen station in Montgomery County, and the Cheverly and Greenbelt stations in Prince George’s County all have LQ values that are lower than 0.70. The lowest value for a metro station located in the downtown core is for L’Enfant Plaza with an LQ of 0.81.

Figure 4 Location Quotients of the FIRE Industries in the WMATA Metro Station Areas in 2010
Spatial Analysis of Firm Distribution in the DC Region

Figure 5 provides overall firm densities for the study area by census block in 1990, 2000, and 2010. Analyzing the data at a small geography shows where in the study area firms are the densest at a small scale, as well as the overall distribution of firms in a macro scale. There is a great deal of firm density in downtown Washington DC from 1990, and remains through 2010. At the same time, many other areas besides downtown DC gained firm density over the 21 year period, as shown in the extent of red blocks in 1990 and 2000. Some of the first ring suburbs, such as Silver Spring, Bethesda, and Rockville in Montgomery County, Maryland show high density along the Red line. However, in Prince George’s county, areas with higher firm density can be found outside the I-495 beltway and along the train track located south of its border with Montgomery County.

The overall trend of firm distribution can be summarized, using simple spatial statistics. In Figure 1, three ovals in the main map show directional distributions (standard deviational ellipse) of firms of all industries in the study area, while circles in one of the inset maps show mean centers of the firm distribution within the study area. As the size of each oval represents the level of geographic extent, the ovals in Figure 1 indicate that the firm distribution became more dispersed across space—the smallest oval being for 1990, the medium size for 2000, and the largest in 2010. The direction of dispersion is toward the periphery of the study area along the north-northwest direction, which is close to the axis of the study area, and toward the northeast direction. All circles of the mean centers are found south of the geographic mean center indicated by the green dot, demonstrating the dominance of the central business district (CBD) to attract firms. Examining more closely, the mean firm distribution center moved north in the 1990s, swung toward east in the early- and mid-2000s, and made a big move to north-west in 2010. While Silver Spring and Bethesda, Maryland have shown a great deal of growth, firms clustering outside of the beltway in Prince George’s County may have contributed more to the distribution of the mean center in the 2000s. These firms are further from the geographic center than the clusters within Montgomery County, and thus their distance from the center is weighted more heavily.
Figure 5 All Industry Firm Density by Census Block in 1990, 2000, and 2010
Figure 6 shows the Getis-Ord Gi* statistics by census block in order to present “hot spots” and “cold spots,” that is, where the clustering of firms occurs in 1990, 2000, and 2010. Areas on the map that are shown in red indicate clusters of blocks with high firm density values, while areas represented in blue show clusters of blocks with low values. It should be noted that “hot” and “cold” are a relative measure only within each year (or map), as standard deviations are used. As we have seen in Figure 5, firm density increases for most areas from 1990 to 2000 and to 2010. Therefore, it is likely that cold spots in 2010 have higher firm density than in 2000, but that these areas were outpaced by most of the other areas in terms of an increasing rate of firm density. Some patterns identified in Figure 5 are more clearly pronounced in Figure 6. While firms have historically clustered in downtown Washington DC, recent trends show firms having clusters along Wisconsin Avenue/the Red line and in Silver Spring in Montgomery County. The area within the beltway in Prince George’s County appears to be cold, while areas beyond the beltway within the county see more hot spots in 2010. In short, while a high level of influence of Metro station presence on firm distribution can be seen in Montgomery County, the influence of proximity to the beltway seems more important in Prince George’s County.

Spatial-temporal Analysis of Firm Distribution in the DC Region

We also used two techniques to explore spatial-temporal characteristics of the firm growth distribution within the study area from 1990 through 2010. Figure 7 shows the annual change in the number of firms in 612 census tracts within the study area. The data are displayed in 3D, with time being represented by the z-axis placed for a centroid of each census tract. The symbology of the data is set up so that a series of dots on each z-axis represents one year interval. The sizes and colors of dots show the scale and sign of a net change in total firms—green for a positive change and red for a negative change.

While not providing great detail as it is still in the development phase of full analysis, Figure 7(a) is a meso-scale view of the spatial-temporal analysis with a focus on downtown Washington DC, while Figure 7(b) through (d) shows micro-scale views of three selected areas. Figure 7(b) shows a great deal of net growth in the Bethesda Red line station area, with nearby census tracts showing nearly unanimous positive net change. In the area of the Largo Town Center Blue line station shown in Figure 7(c), the census tract encompassing the metro station had growth in each year of the study period, with more substantial growth after the opening of the station in 2001. Lastly, the White Flint metro station shown in Figure 7(d) had a great deal of variation in terms of net firm change, as the dots show change in both magnitude and directionality over years.
Figure 6 Hot Spots of Firm Distribution in 1990, 2000, and 2010, using Getis-Ord Gi* Z-scores
Figure 7 Spatial-temporal Analysis of Firm Growth in the DC Region

(a) Downtown DC

(b) Bethesda

(c) Largo Town Center

(d) White Flint
Relocation Data Analysis

Firm relocation flows were analyzed for all firms as a whole and for each of the five industries under study individually. Figure 8 shows the net gain or loss in the number of firms by industry for the aggregated station buffer area in the study area to all of the four other geographic areas between 1990 and 2010. The results shown in Figure 8 focus on “relocation,” and do not take into account births and deaths of firms. Over the 21 year period, the station areas experienced a net loss in all industry firms, as well as each of the five selected industries, due to relocation.

Examining the results more closely by the “destination” area after relocation, the “station area-to-MWCOG” relocation shows the largest net loss in all industry categories, while the “station area-to-Maryland” relocation also shows net loss across the categories. While the “station area-to-station area” relocation is also a net loss except the professional service industry, the “station area-to-external” relocation is a net gain except the accommodation and food services industry.

In short, through the relocation process, the areas of the 66 WMATA Metro stations in DC and Maryland attracted firms from the outside of DC/Maryland, but lost firms to the area outside the station area within the region between 1990 and 2010. It is important to note that relocating firms are a small fraction of the number of firms that move to locations near metro stations. The number of firms moves is substantially lower than the number of firms that are present at any time in the study period, which is clearly shown when we compare the numbers in Figure 8 with those in Figure 2.

Figure 8 Net Gain or Loss in the Number of Firms by Industry between the Station Buffer Area and All Geographic Areas

![Figure 8](image)

Figure 9 shows the net number of firms that moved to and from each of the geographic categories to the individual station buffer for 15 stations with the largest net loss and 10 stations with the largest net gain in the number of all industry firms. Figure 10 shows the number of net moves by Metro station between 1990 and 2010—(a) all industries and (b) the FIRE industry. The size of dot indicates the number of net moves, while red and blue colors show net loss or gain respectively. It should be noted that there are overlaps between station areas in the DC’s core that lead to more than one count of relocation. Figure 9 and Figure 10 clearly show a
substantial net loss at stations in the western side of DC (its central business district shown in the left side of the inset map—Farragut North, Farragut West, DuPont Circle, McPherson Square—and a net gain on the eastern side—Gallery Place-Chinatown, Mt. Vernon Sq.-Convention Center, Judiciary Square, National Archive-Navy Memorial, and Federal Triangle. Farragut North and Farragut West are the core of the central business district and overall experienced a very high volume of relocations, each with over 4,000 firms arriving and over 5,000 firms departing (Figure 9). About equal numbers of sizable relocations either net loss of net gain can be found within the DC outside its central district (Figure 10). A closer examination of data in Figure 10 reveals that the four downtown stations in the central business district had the largest net loss of firms to other station areas and to the MWCOG. These stations also experienced a very high volume of moves overall, both into and out of the station areas.

The three of the top ten firm gainers—Bethesda, Friendship Heights, and Van Ness-UDC—are located along the Red Line in peripheral densely-developed urban areas of Washington and just across the border in Montgomery County. Stations along the Red Line in DC and Montgomery County showed some gains. The station that saw the most losses is Wheaton in Montgomery County with 27 firms that moved to locations external to Maryland and DC. Other net gainers are terminal stations, Shady Grove on the Red Line, New Carlton on the Orange Line, and Largo Town Center on the Blue Line. In particular, Largo Town Center, in Prince George’s County gained nearly as many firms from the MWCOG region as Bethesda, which compensated for the lack of positive gains in the other categories. Looking at FIRE firms specifically, there is a similar pattern of net losses at stations serving the CBD and net gains at downtown stations east of the CBD and in the suburbs.

**Figure 9 Net Moves by Metro Station: 15 Net Loss Stations and 10 Net Gain Stations**
Figure 10 Net Moves by Metro Station Area from 1990 to 2010: (a) All Firms and (b) FIRE Firms
6. SUMMARY OF ANALYSIS FINDINGS AND CONCLUDING REMARKS

In the descriptive study presented in this paper, we conducted economic, spatial, and spatial-temporal analysis of the National Establishment Time Series (NETS) data in order to explore three questions regarding the distribution of firms across the DC metro region and in relation to WMATA Metro stations. First, the analysis of location quotients (LQs) identified the five industries—finance, insurance, and real estate (FIRE), professional services, arts and entertainment, healthcare, and accommodation and food services—have a strong presence within the 0.5 mile network walking distance from the 66 WMATA Metro stations in Washington DC and Maryland, while some of these industries were also identified as industries with a growing presence around transit stations by a few other studies. We also found that the professional services industry increased the number of firms within station areas the most amongst the selected five industries during the period from 1990 to 2000, being followed by the FIRE industries. Within the FIRE industries, small firms with 2 to 10 employees were found to be a major driver for the growth within the station areas in the region.

Second, the spatial analysis showed a large variance of LQ values of FIRE industries across the metro stations, while a concentration of high LQ values was found along the western portion of the Red line and in downtown Washington DC. Two basic spatial statistics showed the overall trend of suburbanization of firm locations, despite the continuous dominance of downtown DC, with a shift toward the north over time, indicating the higher growth rate in Montgomery Country. The analysis of firm density over time, combined with the hot spot analysis, showed a substantial growth of firms in some first ring suburban areas along the metro line outside downtown DC in Montgomery County, indicating a certain level of influence of station proximity on firm locations in a continuous process of job suburbanization in the Washington DC metro region. In the neighboring Prince George’s county, however, a concentration of firms was found farther outside of Washington DC without much connection to metro stations. Spatial-temporal analysis techniques were introduced to identify clusters of firms within the time dimension as well as across space, so that we could find, for example, when in the study period several station areas gained more firms than in other years.

Lastly, the analysis of the firm relocation data found that the WMATA Metro station areas attracted firms from outside of DC/Maryland, but lost firms to the area outside the station area within the region between 1990 and 2010 through the relocation process. It also showed that there is a large variance in terms of net gain and net loss of firms in the FIRE industries among the station areas, which is pronounced by substantial net loss in the western part of downtown DC and substantial net gain in the eastern part of downtown, at a few stations along Red line in Montgomery County, and at a few terminus stations in Prince George’s County. In addition, we found that relocating firms are a small fraction of the number of firms that move to locations near metro stations. Therefore, it is likely that the firm relocation process—or a firm redistribution process in other words—has little influence on the overall firm distribution within the station proximity and for the region.

This study contributes to the literature on the effect of transit investment and TOD on economic development, particularly addressing the question of net effects for locations beyond the immediate station area. The analysis findings have policy implications. First, as firms in the five industries are more attracted to station areas, local governments and WMATA are recommended to work with developers to accommodate any particular needs of these industry
firms in terms of office space, amenities, and services in order to promote economic
development around stations. As small firms (2 to 10 people) make up the greatest proportion of
local firms in the station areas, as well as its outside, local governments are encouraged to create
policies that are friendly to small business for promoting TODs. As firm relocation is a small
fraction of the overall firms in the region, jurisdictions promoting TODs should tailor their
efforts on attracting new firms and supporting firms currently in the station area, rather than
attracting firms that exist somewhere else in the same region.

As the first step of research to analyze firm distribution in relation to station proximity, the
findings, as well as the process, of the descriptive analysis has lead us to future research agendas.
First, while a high level of influence of metro station presence on firm distribution can be seen in
Montgomery County, the influence of proximity to the beltway seems more important in Prince
George’s County. While these two different types of transportation accessibility may attract
different types of industries, it is important to determine what factors can make this difference in
the two different counties. In particular, it is important to examine the effects of transit access
and highway access, as they seem to work differently in the two counties. Second, while transit
access is correlated with firm clusters in at least part of the study area, what is the distance of the
effect of transit access, net of other influential factors. Third, it may be the case that new firms
are attracted to areas in the proximity of metro stations in the Washington DC region for some
expected advantages, while some firms may move to the suburbs to take advantage of lower land
costs passively after they establish business. A question arising here is whether or not these firms
could be retained within the area of station proximity in suburbs, while not in downtown
Washington DC. More jobs around metro stations in the suburbs would help to reduce
directional peaking of commuting travel demand and increase operating efficiency of transit
service. Fourth, one important but difficult-to-answer question is what agglomeration effects
(e.g., sharing information and face-to-face communication) can possibly explain for attracting
the five industries with a strong presence in the station areas in this region. Finally, while
spatial-temporal analysis is considered useful to gauge the effect of rail station presence on firm
locations as it is intrinsically a temporal process, it requires more refinement to go beyond data
visualization and descriptive analysis.

7. ACKNOWLEDGEMENT
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### Appendix A

**Location Quotients for All Industries, for year 2010**

<table>
<thead>
<tr>
<th>NAICS Industry</th>
<th>Firms</th>
<th>Firms</th>
<th>LQ</th>
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<tbody>
<tr>
<td>NA</td>
<td>91</td>
<td>6</td>
<td>0.27</td>
</tr>
<tr>
<td>Agriculture</td>
<td>685</td>
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<tr>
<td>Mining</td>
<td>76</td>
<td>19</td>
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<tr>
<td>Utilities</td>
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<tr>
<td>Construction</td>
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<td>1,270</td>
<td>317</td>
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<td>1,939</td>
<td>338</td>
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<tr>
<td>Wholesale</td>
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<td>4,465</td>
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<tr>
<td>Transportation and Warehousing</td>
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<td>577</td>
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