Does rail transit access affect firm dynamics? Analysis of firm births and closures in Maryland, USA

Basheer Saeed
University of Duhok
Basheer.saeed@uod.ac

Hiroyuki Iseki
University of Maryland, College Park
hiseki@umd.edu

Abstract: Firm birth and firm closure are two interrelated dynamics relevant to measuring economic growth, yet most studies focus on firm birth only. Public transportation infrastructure may facilitate firm birth, but it may also avert firm closure through improved accessibility that can consequently lead to increased local density hence agglomeration economies. This study analyzes firm births and firm closures using the National Establishment Time Series (NETS) panel data from Maryland from 1991 to 2009. By examining both birth and closure patterns, this study estimates the likelihood of firm retention for areas in proximity to passenger rail stations of multiple levels of maturity, while controlling for a number of potentially confounding factors.

Positive and statistically significant relationships are found between proximity to the passenger rail stations and the rates of firm births in Maryland, regardless of differences in the level of maturity of stations. From 1991 to 2009, areas within close proximity to passenger rail stations in Maryland experienced a wide range of rates of growth in firm density, depending on the year of station opening. The results suggest that well after the introduction of rail stations, areas near passenger rail stations gain belated economic benefits shown by higher likelihood of firm retention around the mature rail stations opened before 1990. In comparison, areas near the less mature stations that opened after 1990 had predominantly lower likelihood of firm retention. Planners and policymakers should be proactive in directing development near rail stations by adopting a variety of measures and policies that support or are at least consistent with transit-oriented development (TOD).

Article history:
Received: February 7, 2023
Received in revised form: May 28, 2023
Accepted: August 30, 2023
Available online: November 3, 2023

1 Introduction

Since the 1970s, the number of passenger rail systems in the United States, both heavy and light rail, has more than tripled from 22 rail transit systems in 1970 to 88 in 2015. Proponents of rail infrastructure often justify such substantial investments in rail transit systems because of their contributions to: (1) improved overall efficiency of transportation systems, (2)

https://dx.doi.org/10.5198/jtlu.2023.2343
ISSN: 1938-7849 |

The *Journal of Transport and Land Use* is the official journal of the World Society for Transport and Land Use (WSTLUR) and is published and sponsored by the University of Minnesota Center for Transportation Studies.

environmental sustainability, (3) reducing automobile dependence and congestion, and (4) promoting economic development. While many studies have examined the first three influences of rail investments (Bernick & Cervero, 1997; Katz & Puentes, 2005; Newman & Kenworthy, 1999), the contribution of rail transit investments to economic development is, relatively speaking, less understood. This subject has increasingly attracted close attention by transportation scholars and economists, as well as local officials and planners, as many cities have been building, expanding, or are considering building rail systems with the planning goals of transit-oriented development (TOD) and job accessibility improvement in addition to the conventional transportation and environmental goals. For example, the 16-mile Purple Line light rail is proposed by the Maryland Transit Agency (MTA) with a clear emphasis on the supply side benefits of the project, which are the community benefits related to economic productivity such as increased jobs, income and wealth (MTA, 2015). The patterns of firm dynamics within regions and urban areas are important indicators of change in employment and economic growth. New firm birth to an urban economy signals innovation and is an indicator of economic growth (Chatman et al., 2016; Reynolds, 1994). However, due to a lack of empirical evidence, policymakers and academics disagree about the magnitude of impact that rail transit infrastructure has on the patterns of firm dynamics.

The objective of this study is to examine the impact of rail transit investments on the patterns of firm dynamics, analyzing firm birth and firm closure patterns within census blocks within short distances from stations of three passenger rail transit systems operated in five jurisdictions of the State of Maryland. This study particularly makes a distinction between rail stations opened more recently and those with a longer period passed since their opening to take into account the temporal factor of economic development; the more mature a rail station, the higher the likelihood that the area around the station has already reached a development saturation point leaving limited or no potential for additional growth.

Following this introduction, the next section provides a literature review of studies that empirically examine the association between passenger rail investments and the patterns of firm birth. The third section describes the data used in the analysis of this study and the way the dependent and control variables are structured. The fourth section covers details on the methodology and provides a reason for the use of negative binomial regression method to examine the impacts of rail station proximity on firm birth and firm closure across multiple firm size categories. The fifth section reports the analysis results, and the paper concludes with discussions and implications for planning and policies.

2 Literature review

Firm birth and closure dynamics are primarily driven by entrepreneurial innovation, market opportunity, and regional characteristics such as skilled labor, infrastructure, and money as described by Capello (2010a). Closures, on the other hand, are an inevitable component of economic growth through creative destruction and can be caused by a variety of circumstances such as competitive pressures, altering consumer preferences, technology obsolescence, or changes in the regional business environment. Empirical research, such as those by Yu et al. (2018) and Graham and Gibbons (2019), emphasize the critical importance of regional characteristics and infrastructure. Improved rail transit, for example, encourages industrial agglomeration, helps the formation of new businesses, lowers closure rates, and has a favorable impact on broader economic parameters.

Research confirms that geographical features, especially infrastructure, have a major impact on business dynamics. Schuetz (2015), for example, observed that rail transit infrastructure enhances local retail activity, which is consistent with prior findings (Baum-Snow & Kahn, 2000; McDonald, 2007). Furthermore, Ray (2017) demonstrated that not just the presence of rail infrastructure but also its construction has an impact on surrounding enterprises, supporting the findings of Giuliano (2004) and Boarnet and Crane (2001). This body of research confirms the findings of Capello (2010b), Yu et al. (2018), and Graham and Gibbons (2019) by emphasizing the significance of infrastructure in determining firm birth and closure dynamics.

The literature on the economic impacts of transit investments is largely focused on aspects related to property value and total employment (Bowes & Ihlanfeldt, 2001; Mathur & Ferrell, 2009). An important but least discussed economic aspect of transit investments is their impact on changes in the patterns of firm dynamics. Some available evidence from the literature on firm dynamics suggests that investments in rail transit contribute to denser employment clusters and even denser and more diverse cities in terms of economic activities, leading to higher economic productivity (Chatman et al., 2014; Melo et al., 2013).

Although firm birth tends to be a focus of economic development debate at the local level, a complete picture of the dynamic process of urban economics needs to also include firm closure and relocation. In a particular area, the number of firm births is not a sufficient indication, per se, of a net economic gain or loss. Firm births can merely be the result of the closure of existing firms in a process called "creative destruction," coined by Schumpeter (Schumpeter, 1934). Moreover, within this scarce literature on the impacts of rail investment on firm dynamics, most of the existing studies examine the aggregate economic growth, comparing either multiple cities, urbanized areas, or metropolitan areas (Chatman et al., 2016; Holl, 2006). Such studies do not provide much information to planners and elected officials regarding the impacts that can be expected in a small geographic scale (such as individual station surrounding areas), especially in TOD projects. This study analyzes the dynamics of firm birth and firm closure. Firm relocation is not included in the limited space of this paper because of its unique nature in terms of data coding, and because firm relocation requires a distinct analysis approach that takes into account the origin and destination locations of relocating firms.

Firm birth has a positive influence on the economic growth of a region. Job creation and changes in economic structure are the most notable positive externalities of firm birth. While the empirical research on the determinants of firm birth is abundant, a limited number of studies have examined the link between proximity to transportation infrastructure and the number of firm births (Chatman et al., 2016; Coughlin & Segev, 2000; Holl, 2004a, 2004b, 2004c; Melo et al., 2010; Smith and Florida, 1994). Among these studies only two consider proximity to rail station as an explanatory variable in their analysis of firm birth (Chatman et al., 2016; Melo et al., 2010). Yet only one study to date (Chatman et al., 2016) has used micro-level units of analysis (Census blocks) within the metropolitan regions of Dallas, Texas, and Portland, Oregon, to examine the connection between proximity to rail stations and firm birth. These limited number of studies predominantly found a positive relationship between the availability of transportation infrastructure and firm birth. However, there is more to the dynamic process of urban economics than firm birth.

In an economic analysis of firm dynamics, it is important to understand the complex relationship between firm closure and firm birth. Nonetheless, most empirical studies fail to control for, let alone analyze, the rates of firm closure when examining the determinants of firm birth. The rate of firm closure is included as an independent (explanatory) variable in a few empirical studies examining the determinants of firm birth (Chatman et al., 2016; Sutaria & Hicks, 2004).

The effect of firm birth on firm closure can be either positive or negative. Over time, more firm births may lead to more firm closures when a process called "competition effect" is at work. This means existing firms fail to compete with newly formed firms to meet market demand and then subsequently exit the economy. On the other hand, more firm births may lead to less firm closures when the market demand increases for business products and services in a process called “multiplier effect” (Cainelli et al., 2014; Johnson & Parker, 1996; Sutaria & Hicks, 2004) The multiplier effect hypothesizes that firm births cause more future firm births and impede future firm closures. Moreover, the process of firm birth and firm closure can be considerably heterogeneous across different geographical areas. In other words, existing firms go out of business (i.e., fail to make profit or to compete with existing firms) and new firms emerge disproportionally across different geographical areas.

The empirical studies on firm dynamics provide an extensive list of factors that influence firm birth and firm closure (Acs & Armington, 2006; Browning, 1980; Reynnolds, 1994), which can be categorized into five main groups of factors: (a) market conditions related to supply and demand, (b) agglomeration economies (urbanization and localization economies), (c) policy environment, (d) regional context, and (e) firm-specific (non-tangible) factors. Market conditions normally include variables on socio-economic characteristics such as population, income, race, and level of education. Localization and urbanization economies (agglomeration economies) include variables on population and employment densities and firm density. Firm agglomerations may also play an intermediary role between transit investments and the patterns of firm dynamics. That is, transit investments influence changes in firm agglomeration (density), which consequently influence changes in firm dynamics due to localization and urbanization externalities.

Government policies can also influence the patterns of firm dynamics. Based on data availability, a few empirical studies use tax policy (or government spending policy) as a proxy for the policy environment within a region (Coughlin & Segev, 2000; Reynolds, 1994: Smith & Florida, 1994; Sutaria & Hicks, 2004). To operationalize spatial context, the most common measure and most familiar to urban planners, is the distance to central business district (CBD) (Chatman et al., 2016). Other non-tangible factors can also influence the patterns of firm dynamics but can hardly be quantified since they are subjective in nature, such as factors related to the emotional and cultural preferences of entrepreneurs and business owners. Data on non-tangible factors and personal preferences are nearly impossible to objectively quantify since they are not necessarily supported by rational arguments (Risselada et al., 2013). This study, therefore, focuses on tangible and quantifiable factors in the analysis of firm birth and firm closure.

Firms of different sizes are likely to respond differently to proximity to passenger rail stations as well as other determinants of firm birth because larger firms are inherently different in structure from smaller firms (e.g., larger firms are normally more well established than smaller ones) (Chatman et al., 2016). Compared to smaller firms, firms with higher numbers of employees might also benefit more from improved accessibility to the labor force that rail systems provide, and savings from less provisions of subsidized parking for employees, especially in the case of US cities.

In the literature, the use of macro geographic units of analysis in earlier studies have generated conflicting findings when examining the connection between transportation networks and the patterns of firm dynamics, especially in the case of rail transit networks (Bacher et al. 2013; Coughlin & Segev, 2000; Holl, 2004a, 2004b, 2004c; Melo et al., 2010; Smith & Florida, 1994). In addition, different studies used diverse types of variables as a dependent variable, in combination with different regression methods. Earlier studies used percentages or area density as a dependent variable in combination with simple ordinary least square (OLS) or fixed effect panel regressions to examine the rate of firm birth (Armington & Acs, 2002; Audretsch & Fritsch, 1994; Reynolds, 1994; Sutaria & Hicks, 2004). More recent studies treat firm births as discrete events, and assume that the process of firm birth, measured as a count variable, follows a Poisson or a negative binominal distribution. As a result, count models are considered more suitable for firm birth analysis (Chatman et al., 2016; Holl, 2004a, 2004b, 2004c; Melo et al., 2010).

Moreover, urban planners typically define areas designated as suitable for transit-oriented development as those within a half-mile radius from rail stations (Hess & Almeida, 2007). The half mile designation is often justified as being the walking distance that people on average are willing to take to reach a station. Studies that examine property values in relation to rail stations often assign a binary variable to indicate whether or not properties are located within one-quarter or a half-mile of a station (Cervero & Duncan, 2002; Pan, 2013). However, a few more recent studies have presented evidence that rail stations have impacts that extend beyond the conventional half-mile buffer to reach up to one mile away (Holl, 2004a, 2004b, 2004c; Melo et al., 2010; Nelson et al., 2015).

Collectively, the literature on the impacts of rail transit investments on firm dynamics reveals relatively scarce research on this topic, disproportionate focus on firm births, a variety of influential factors, and lack of consensus on units and scale of analysis. The recent studies have used a count variable as a dependent variable to examine of firm birth and firm closure in Poisson or negative binomial regression models.

3 Research design

Based on the literature review, this study examines the impact of rail transit investments on firm births and firm closures in a micro geographic scale, applying negative binomial regression method. Limitations in the quality of data have restricted the number of variables considered in past empirical studies that examine the patterns of firm dynamics in relation to transit infrastructure. This study contributes to the literature in the field of firm dynamics by conducting a comprehensive examination of the determinants of firm birth and closure using a large and more detailed dataset.

3.1 Research question/hypothesis

This research hypothesizes that areas within short walking distances to passenger rail stations experience, on average, positive net gain in firm birth because of improved accessibility through transit infrastructure, compared to areas farther away from the stations. The research also hypothesizes that the magnitude of effect experienced in areas near the transit stations varies across firms in different size categories. This study applies a random effects negative-binomial panel model specification to the dataset that was constructed, using data from multiple data sources, and analyzes the relationship of the counts of firm births and closures in relation to rail transit investments in five Maryland counties.

3.2 Study area, data, and data sources

Figure 1 shows the study area, which includes five counties in Maryland. These five counties have passenger rail stations of MTA light rail, subway, and commuter rail,[1] as well as WMATA's Metrorail. The rail stations were opened in different years over a 26-year span. The Washington Metrorail system was opened in 1978 but most of the stations were opened after 1984. The most recent stations were opened in 2004. Meanwhile, the Baltimore Metro Subway has a total of fourteen stations operating along a 15.5-mile-long route that crosses Baltimore County and the city of Baltimore. The system went through three phases of construction. The first nine stations were opened in 1983 along an eight-mile route within the city of Baltimore. In 1987, three more stations were added to the metro system along a six-mile route within the suburbs of Baltimore County located northwest of the city of Baltimore. In the last phase, two more stations were opened to the public within the city of Baltimore in 1995.

[1] The Maryland Area Regional Commuter (MARC) stations are not included in the analysis because the commuter rail predominantly serves dispersed areas with low residential density and rural development patterns (Liu et al, 2016).

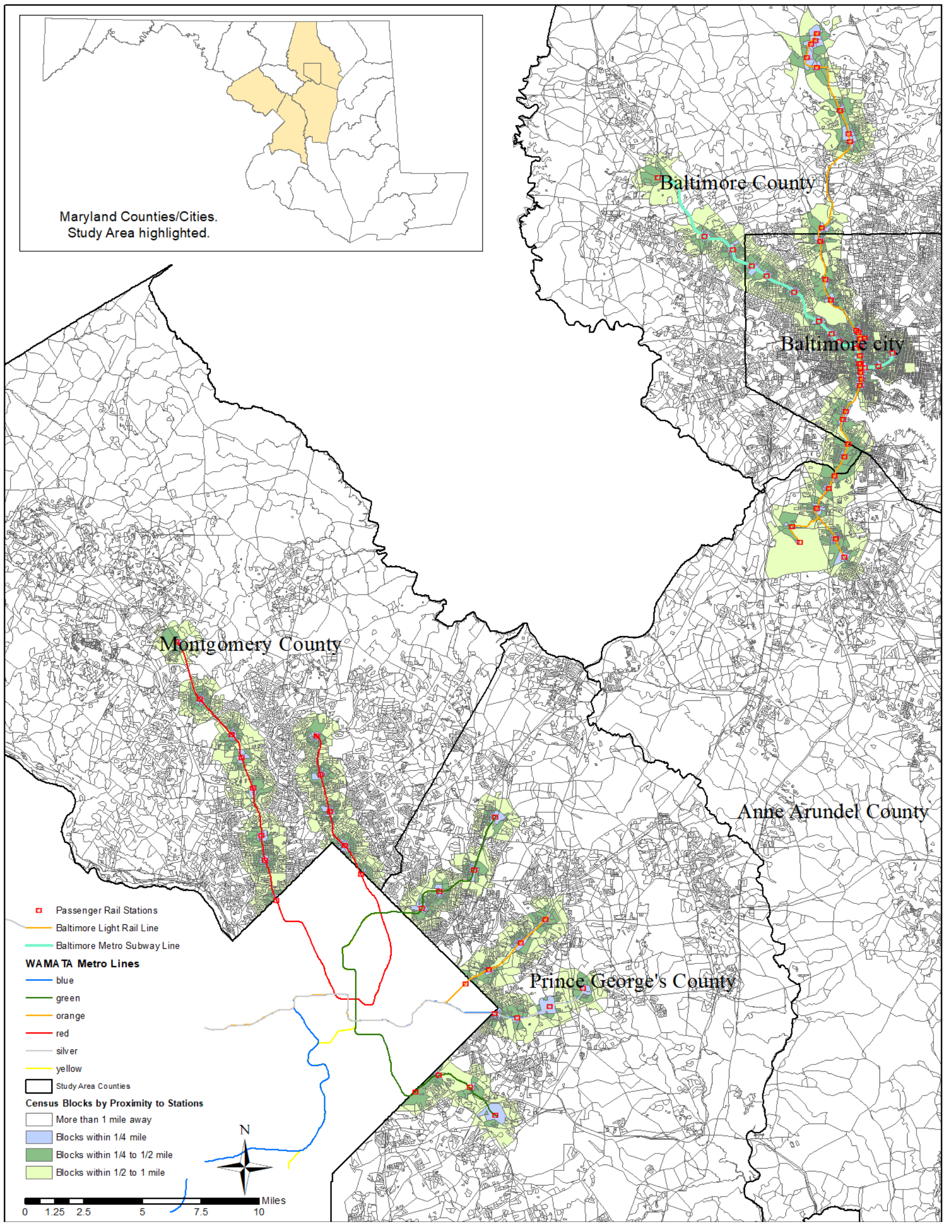

Figure 1. Map of the study area

Table 1 provides descriptions, measurements, and data sources of variables in this study. The main data source is National Establishment Time-Series (NETS) dataset. NETS database offers the advantage of a detailed account of dynamics of the U.S. economy and was made available by Walls & Associates which converted the archival establishment data into a time-series database of establishment information (Walls, 2008). NETS microdata is a reliable data source for studying static business activity in high detail (Barnatchez et al., 2017). The data for two dependent variables in this study—the count of firm birth and the count of firm closure by *census block*—are based on the first and last year of each firm's presence and the firm size (number of employees), which are constructed from data of individual firms over the period between 1991 and 2010. The smallest geographic units of analysis in the U.S. Census—Census block—was chosen to examine micro patterns of firm dynamics and accurately determine the association between areas within short walking distance of rail transit stations and the patterns of firm birth and firm closure, because, unlike road networks, rail transit networks tend to be spatially scattered and often accessed by walking. At the same time, other variables in the analysis are collected at the Census block-group from 1990, 2000, and 2010 Decennial Census. Multiple Census blocks share socio-demographic data from the same Census block group that contains their centroid.

Table 1. Descriptions, measurements, and data sources of variables in the study

Variable	Mean	Std. Dev.	Min	Max	Geographic Resolution	Data Source
Firm dynamic variables						
Birth counts	1.96	8.31	0	552	Census block	1
Closure counts	1.23	8.15	0	497	Census block	1
Proximity to rail station variables						
Distance to Rail station (in mi)	4.85	4.85	0.01	26.39	Census block	2
Group A stations: Blocks within <=1/4 mile	0.01	0.11	0	1	Census block	2
Group A stations: Blocks within 1/4 to 1/2 mi	0.03	0.17	0	1	Census block	2
Group A stations: Blocks within 1/2 to 1 mi	0.07	0.25	0	1	Census block	2
Group B stations: Blocks within <=1/4 mile	0.01	0.11	0	1	Census block	2
Group B stations: Blocks within 1/4 to 1/2 mi	0.02	0.15	0	1	Census block	2
Group B stations: Blocks within 1/2 to 1 mi	0.05	0.22	0	1	Census block	2
Group C stations: Blocks within <=1/4 mile	0.0001	0.01	0	1	Census block	2
Group C stations: Blocks within 1/4 to 1/2 mi	0.0004	0.02	0	1	Census block	2
Group C stations: Blocks within 1/2 to 1 mi	0.0026	0.05	0	1	Census block	2
Agglomeration variables						
Population per sq. mi. (in 1000s)	6.18	7.21	0	165.78	Census block group	2
Employee per sq. mi. (in 1000s)	2.89	3.15	0	92.29	Census block group	2
Number of firms	4.1	17.53	0	894	Census block	1
Average age of firms	11.33	15.69	0	400	Census block	1
Socio-economic variables						
Median HH Income (in $1000s)	61.57	35.7	0	250	Census block group	2
Unemployment rate	5.85	5.95	0	100	Census block group	2
Percent college educated	32.78	22.92	0	100	Census block group	2
Percent African-American	23.34	34.21	0	100	Census block group	2
Median housing rent (in $1000s)	0.84	0.49	0	2	Census block group	2
Property tax (in $1000)	1.26	0.6	0.12	2.76	County/City	3
Spatial context variables						
Transit to auto accessibility ratio	0.11	0.11	0	1	Census block group	4
Distance to highway (in mi)	1.67	1.64	0.003	16.89	Census block	5
Distance to CBD (in mi)	10.28	6.67	0.02	32.4	Census block	5

1. The source is NETS data from 1990 to 2009.
2. The source is U.S. Census 1990, 2000, and 2010.
3. The source is the Maryland Department of Assessment (2010).
4. The source is EPA's Smart Location Database (SLD) (2010).
5. Calculated using TIGER GIS shapefiles.

The analysis accounts for other variables using data from years 1990, 2000, and 2010 to cover changes in socio-demographics, agglomeration, and spatial context of the study area. These three periods of time are selected for the analysis because demographic data at the micro level (i.e., census block group) are only available within the U.S. decennial census. The characteristics of local population include median household income, median housing rent, share of the population that is African American, share of the population that is college educated, and share of the population that is unemployed—all collected from the U.S. Decennial Census at the Census block group level. The agglomeration measures included in this study are population and firm densities.

The analysis also includes time-invariant measures: transit-to-auto accessibility ratio (at peak time from year 2010); distance to nearest highway ramp; and distance to the nearest central business district (either Baltimore City or Washington DC CBD). The transit-to-auto accessibility ratio variable is calculated using transit and auto accessibility measures from the Smart Location Database (SLD) (U.S. Environmental Protection Agency, 2018), a database developed by the Environmental Protection Agency (EPA) for every Census block group in the United States. The SLD transit and auto accessibility measures are generated by EPA using demographic and travel data from 2010 U.S. Census.

It important to note that the economic trend in the two metropolitan areas, Baltimore and Washington DC, potentially influences the findings concerning firm birth and closure dynamics in this case study. For example, higher GDP growth in the Washington DC area compared to the Baltimore area (32% versus 21%) between 2001 and 2010 might indicate more favorable conditions for firm births, and possibly a more resilient business environment, leading to fewer firm closures (U.S. Bureau of Economic Analysis, 2023). The faster-growing economy could provide more opportunities and resources for new firms, while also offering established firms a more robust market, reducing the likelihood of closures.

3.3 Analysis method

This study applies a random effects negative-binomial panel model specification (Hausman et al., 1984) to a regression analysis of the counts of firm births and deaths, using maximum likelihood estimation. Poisson regression specification was not used because the data in this study exhibited overdispersion, where the variance of a distribution is larger than its mean, as is often the case with real data of firm births and closures. Under these circumstances, Poisson regression models are not a good fit for count variables because the Poisson distribution assumes its variance is equal to its mean. Negative Binomial model (NB) estimates the over-dispersion parameter alpha (α), which makes the model a better fit for count data than Poisson model. In addition, the random effects model was chosen over the fixed effect model because some of the explanatory variables are time-invariant, impeding the use of fixed-effects models (Bell & Jones, 2015; Chatman et al., 2016).

Unlike most of the previous studies, this analysis considers four firm size categories: (1) firms with sole proprietor; (2) firms with more than one employee; (3) firms with five or less employees; and (4) firms with more than five employees. Separate regression analysis was conducted for each of the four firm size categories, as well as for all of the firm sizes.

The count of firm birth and firm closure are analyzed within three consecutive buffer zones (rings) that extend up to one mile from the passenger rail stations. These three buffers from each rail station are: (1) a *quarter mile buffer*, (2) a *quarter to half mile* buffer, and (3) a *half to one mile* buffer. A Census block is considered to be within one of the three buffers if the buffer contains the block centroid.

The patterns of firm dynamics may demonstrate different trends across rail stations with different levels of maturity. The areas around rail transit stations are therefore categorized into three groups in the analysis to account for the variation in the opening year of the stations. Figure 1 shows the Census blocks within proximity to the rail stations that belong to these three different groups located within both Metropolitan areas, Baltimore and Washington DC. The rail stations in Group A are the most mature stations, opened before 1990. Rail stations in Group B are those opened between 1990 and 1998 and rail stations in Group C are the most recent stations within the study area, opened between 2000 and 2004. Dummy variables are included for each of Group A, B, and C stations, setting the rest of stations as the base case.

4 Analysis results

This section starts with the descriptive analysis of trends of area densities of firm births and firm closures in each Census block over time, and reports results of regression analysis with the counts of firm births and closures as a dependent variable. Then, the results of regression analysis using the different dependent variables are combined to get a more comprehensive picture of firm dynamics than the one only looking at firm births.

4.1 Trends of area-density of firm births and closures

Figure 2 provides the trends of firm births per square mile and firm closures per square mile in each Census block over 18 years, considering varied sizes of buffers from the rail stations. Throughout the period of the study, the number of firm births per square mile in each Census block remained the highest in areas within a quarter mile distance from the rail stations followed by areas within a quarter to half mile buffer, in comparison to the rest of the study area. Areas within a quarter mile from passenger rail stations also experienced the highest number of firm closures. Therefore, the economic trend is not positive over time in areas near the stations and in the study area when looking at both the number of firm closures and the number of firm births.

Overall, the study area experienced an economic decline in the period between 1991 and 2008. Within the study area, the number of firm births per square mile was lower than the number of firm closures per square mile in nearly each year between 1991 and 2008 (Figure 2). On the other hand, areas near the passenger rail stations experienced higher number of firm births compared to firm closures for longer periods than the study area. Census blocks located within a mile of the passenger rail stations experienced lower number of firm closures compared to firm births for several years during the period between 1991 and 2008. Controlled statistical analysis is needed to test whether or not areas within proximity to rail stations indeed experience lower probability of firm closure relative to the probability of firm birth, compared to control areas located more than a mile from the rail stations.

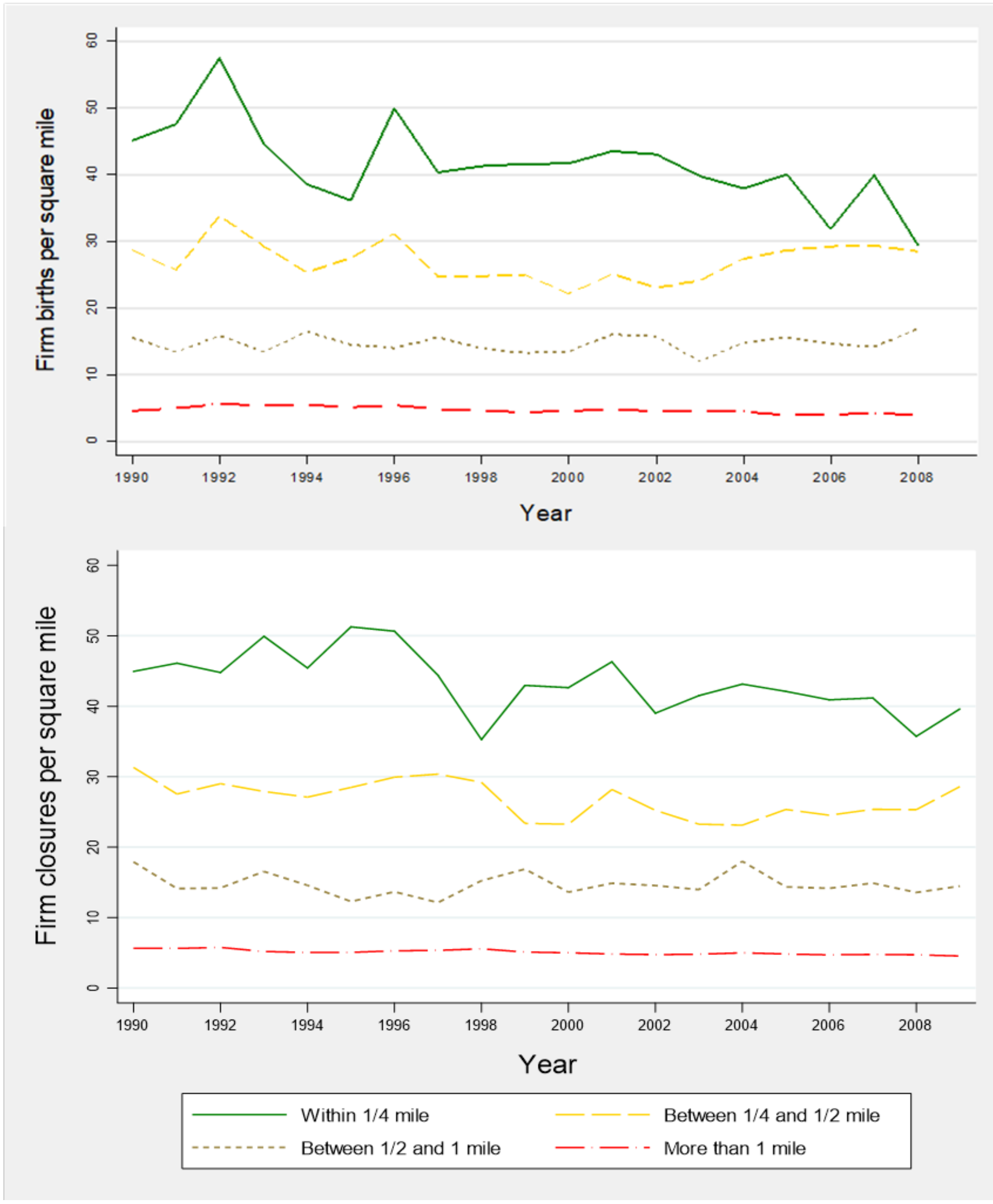

Figure 2. Trends of area densities of firm births and firm closures (per square mile) by Census Block

4.2 Regression analysis of firm birth

Table 2 shows the results from the random-effect negative-binomial regression analysis. The number of firm births per Census block is estimated as a function of distance from the Census block to the nearest station in miles, three distance-to-station buffers, and other control variables. In general, the estimated coefficients of distance to station buffers indicate that the proximity to passenger rail station has a positive influence on the probability of firm birth. The Census blocks in closer proximity to passenger rail stations have experienced higher number of firm births than in the control areas (blocks located more than a mile from the stations).

Table 2. The count of firm birth as a function of proximity to rail stations, agglomeration, and socio-economic characteristics

Dependent variable: Count of firm birth	All Firms	Sole Proprietor	Firms > 1 employee	Firms <=5 employees	Firms >5 employees
Distance to Rail station (in mi)	-0.054***	-0.055***	-0.049***	-0.057***	-0.025***
Group A stations: within <=1/4 mile	0.087	0.011	0.241***	0.047	0.811***
Group A stations: within 1/4 to 1/2 mi	-0.007	-0.008	0.075	-0.019	0.420***
Group A stations: within 1/2 to 1 mi	-0.291***	-0.350***	-0.250***	-0.324***	-0.049
Group B stations: within <=1/4 mile	0.229***	0.339***	0.220***	0.323***	0.089
Group B stations: within 1/4 to 1/2 mi	0.217***	0.266***	0.157***	0.266***	-0.035
Group B stations: within 1/2 to 1 mi	0.279***	0.239***	0.218***	0.312***	-0.086
Group C stations: within <=1/4 mile	0.792***	1.069**	0.849***	1.081***	0.284
Group C stations: within 1/4 to 1/2 mi	0.357**	0.836***	0.142	0.393**	0.19
Group C stations: within 1/2 to 1 mi	0.235***	0.544***	0.038	0.264***	0.062
Accessibility ratio	0.847***	0.609***	0.821***	0.775***	1.136***
Population per sq. mi. (in 1000s)	-0.015***	-0.046***	-0.003	-0.014***	-0.043***
Employee per sq. mi. (in 1000s)	0.037***	0.119***	0.001	0.042***	0.014
Number of firms	0.007***	0.009***	0.007***	0.007***	0.011***
Firm closures	0.000	0.001***	0.001**	0.001***	-0.002***
Median HH Income (in $1000s)	0.013***	0.018***	0.007***	0.014***	-0.011***
Unemployment rate	2.423***	4.455***	0.741***	2.656***	-1.126***
Percent college educated	0.004	-0.177***	0.214***	0.008	0.509***
Percent African-American	0.625***	0.744***	0.581***	0.663***	0.194***
Median housing rent (in $1000s)	0.230***	0.420***	0.096***	0.268***	-0.274***
Distance to highway (in mi)	-0.043***	-0.028***	-0.056***	-0.036***	-0.153***
Distance to CBD (in mi)	0.034***	0.042***	0.034***	0.036***	0.036***
Property tax (in $1000)	-0.032*	0.004	-0.090***	-0.02	-0.294***
Constant	-0.685***	-2.284***	-0.051	-0.934***	1.301***
ln_r Constant	0.761***	0.928***	0.913***	0.777***	1.223***
ln_s Constant	-0.253***	-0.110***	-0.504***	-0.230***	-1.558***
N. of cases	116820	116820	116820	116820	116820
Log Likelihood	-160389.805	-102335.347	-126097.983	-155377.573	-35504.633
chi2	27245.735	19500.111	13257.299	28630.265	3584.268
* $p<0.05$, ** $p<0.01$, *** $p<0.001$					

As this research hypothesized, the influence of proximity to rail stations on firm birth is heterogeneous across all different firm size categories. There are also substantial differences in the magnitude of influence across different station categories based on their level of maturity (i.e., group A, B, and C). For instance, in the *quarter mile* buffer of Group B rail stations, the coefficients range in magnitude between 0.089 for firms larger than five employees to 0.339 for firms with sole proprietor. This is a clear indication that the size of firm is an important factor in the association between proximity to rail station and firm birth.

The results also show that smaller firms (i.e., firms with sole proprietor or less than five employees) are the ones benefiting the most from better accessibility to the passenger rail stations, especially for the less mature rail stations in Groups B and C (i.e., stations opened after 1990) since the coefficients are larger in magnitude for smaller firms. For example, the coefficients for the *quarter mile* buffer of Group B station are $\beta=0.339$ for firms with sole proprietor and $\beta=0.323$ for firms with five or fewer employees, which are much larger in magnitude than the coefficient ($\beta=0.089$) for firms larger than five employees. For larger firms, the results are mixed across the station buffers and levels of maturity.

The results indicate that the proximity to stations has distinct effects on different firm sizes. The proximity of Group A stations within a quarter mile has a significant positive impact on the birth of firms with more than one employee but has no effect on larger firms (>5 employees). The effect is strong for Group B stations across all firm sizes; however, it becomes insignificant for larger firms beyond a quarter-mile. This shows that proximity to Group B stations stimulates the formation of smaller firms, but this benefit diminishes as distance increases for larger firms.

If access to the labor force is the main benefit provided by rail systems, one would expect births of larger firms to be strongly correlated with station proximity. The regression results suggest that this is true only in the case of mature rail stations. Blocks within proximity to the mature rail stations (Group A stations) have experienced significantly higher incidents of firm birth of firms with more than five employees compared to areas near less mature stations (Group B and C stations).

4.3 Regression analysis of firm closure

Table 3 shows the results from the regression analysis examining the number of firm closures as a dependent variable. As discussed in the previous section, areas within proximity to rail stations experienced higher number of firm closures because of high number of firm births. This overall trend is confirmed by the negative signs of estimated coefficients of the continuous distance-to-station variable in Table 3 across all firm-size categories (ranging between β=-0.061 and β=-0.068). The negative distance-to-station coefficients means there are higher numbers of firm closures in areas within close proximity to the rail stations. The positive estimated coefficients of the three station-buffer variables in Table 3 also confirm the existing positive association between areas in close proximity to the rail stations and the number of firm closures. However, there is an exception to the positive association between station proximity and firm closure; the estimated coefficients ranging between β=-0.387 for firms with sole proprietor and β=-0.271 for firms with more than five employees for Census blocks within a *half to one mile* buffer of the mature rail stations (Group A stations) indicate negative probability of firm closure, compared to the probability of firm closure in the base case with stations opened between 1990 and 2004 (Group B and C stations).

Table 3. The count of firm closures as a function of proximity to rail stations, agglomeration, and socio-economic characteristics

Dependent variable count of firm closures	All Firms	Sole Proprietor	Firms > 1 employee	Firms <=5 employees	Firms >5 employees
Distance to Rail station (in mi)	-0.062***	-0.068***	-0.066***	-0.063***	-0.061***
Group A stations: within <=1/4 mile	0.348***	0.233**	0.441***	0.284***	0.672***
Group A stations: within 1/4 to 1/2 mi	0.152**	0.062	0.175**	0.106*	0.280***
Group A stations: within 1/2 to 1 mi	-0.323***	-0.387***	-0.353***	-0.378***	-0.271***
Group B stations: within <=1/4 mile	0.658***	0.588***	0.697***	0.662***	0.728***
Group B stations: within 1/4 to 1/2 mi	0.485***	0.369***	0.461***	0.495***	0.295***
Group B stations: within 1/2 to 1 mi	0.270***	0.244***	0.239***	0.284***	0.118
Group C stations: within <=1/4 mile	1.384***	1.731***	1.071**	1.730***	0.49
Group C stations: within 1/4 to 1/2 mi	1.176***	1.287***	1.035***	1.249***	0.959**
Group C stations: within 1/2 to 1 mi	0.868***	0.769***	0.732***	0.860***	0.655***
Accessibility ratio	1.369***	0.854***	1.283***	1.274***	1.210***
Population per sq. mi. (in 1000s)	-0.045***	-0.056***	-0.037***	-0.045***	-0.043***
Employee per sq. mi. (in 1000s)	0.101***	0.138***	0.074***	0.108***	0.048***
Number of firms	0.005***	0.005***	0.005***	0.005***	0.007***
Firm births	0.005***	0.009***	0.004***	0.006***	0.001
Average age of firms	0.002**	0.004***	0.002**	0.001	0.020***
Median HH Income (in $1000s)	0.019***	0.018***	0.015***	0.020***	0.003***
Unemployment rate	4.626***	5.192***	3.759***	5.049***	1.865***
Percent college educated	-0.483***	-0.608***	-0.140*	-0.486***	0.121
Percent African-American	0.503***	0.805***	0.472***	0.598***	0.136**
Median housing rent (in $1000s)	0.534***	0.581***	0.466***	0.564***	0.379***
Distance to highway (in mi)	-0.066***	-0.027***	-0.092***	-0.052***	-0.164***
Distance to CBD (in mi)	0.031***	0.048***	0.034***	0.033***	0.040***
Property tax (in $1000)	0.113***	0.072***	0.058*	0.096***	-0.065
Constant	-2.388***	-3.755***	-1.545***	-2.741***	-0.494***
ln_r Constant	0.424***	0.719***	0.627***	0.430***	1.187***
ln_s Constant	-0.528***	0.119*	-1.002***	-0.455***	-1.758***
N. of cases	116820	116820	116820	116820	116820
Log Likelihood	-110399.3	-66258.33	-86168.574	-103193.656	-34541.043
chi2	24121.688	13418.113	17184.323	22147.153	4789.795
** p<0.05, ** p<0.01, *** p<0.001*					

The firm closure model shows varying observed impacts across station groups (A, B, C) and firm sizes. For firms larger than five employees, an inverse relationship is found within a *half to one mile* buffer of Group A stations, while closer proximities significantly increase closures. In Group B, proximity up to half mile significantly raises closures across all firm sizes, but no significant impact is found for larger firms within *half to one mile*. Group C stations consistently increase closures across all ranges and sizes. This reveals a nuanced interplay between station proximity and firm size when it comes to firm closures in TODs.

The proximity to all station groups shows a significant impact across different firm sizes, but this impact diminishes as distance increases. Importantly, for larger firms, proximity to Group A stations within a quarter and a half mile is significantly associated with firm closures, indicating that the closer these firms are to these stations, the greater their likelihood of closure. The differential effects across station groups and firm sizes demonstrate the complexity of the relationship between transit accessibility and firm dynamics.

Table 3 also shows that the distance to a railway station and distance to a highway both have statistically significant negative effects on firm closures across all firm types. This indicates that firms value proximity to both, most likely due to enhanced accessibility. The similarity of the coefficients implies that highway accessibility is just as significant as TOD accessibility, highlighting the importance of overall transportation access in company viability.

4.4 Firm retention analysis, combining firm births and closures

Although the past studies on the subject conducted an analysis of firm births and firm closures separately, the comparison of the estimated probabilities of firm closure and firm birth will provide a more comprehensive picture of the impacts of the proximity to rail stations on an economic gain (or loss) in firm dynamics. For instance, when areas near rail stations with positive predicted probability of firm closures are compared to control areas, the same areas may have higher predicted probability of firm birth, resulting in a net positive probability of firm retention. Therefore, the total sum of the predicted probabilities of firm birth and closure is calculated for the three station buffers for the four firm-size categories. To calculate the probability of firm birth and firm closure, the coefficients (βs) from the negative-binomial regression models in Table 2 and Table 3 are converted to the percentage of the probability of effect by the formula [e(β) – 1].

Figure 3 shows the predicted probabilities of firm retention by distance from each group of A, B, and C stations for two firm size categories. Figure 3 shows that lengthy periods of time elapse before areas near the rail stations exhibit higher probabilities of firm birth than probabilities of firm closure (i.e., positive probability of firm retention). That is, areas within a mile of the mature rail stations (Group A) were more likely to retain firms than areas within a mile of recently opened stations (Group B and C). Positive firm retention in an area indicates an increase in firm density. Larger firms with more than five employees have, on average, the highest positive-sum of the predicted probabilities of firm birth and firm closure in areas within short walking distance to passenger rail stations in Group A. Figure 3 shows that blocks located within up to one mile of the mature rail stations (Group A) have experienced a considerably higher predicted probability of retention of firms with more than five employees compared to the control areas located more than a mile from the rail stations. For instance, the probability of the *quarter mile* buffer of the Group A stations to retain firms is 29%, all else held equal, which is calculated by subtracting the estimated probability of firm closure (96%) from the estimated probability of firm birth (125%). Other positive probability of firm retention is found for firms with five or less employees within the *half to one mile* buffer of group A and B stations.

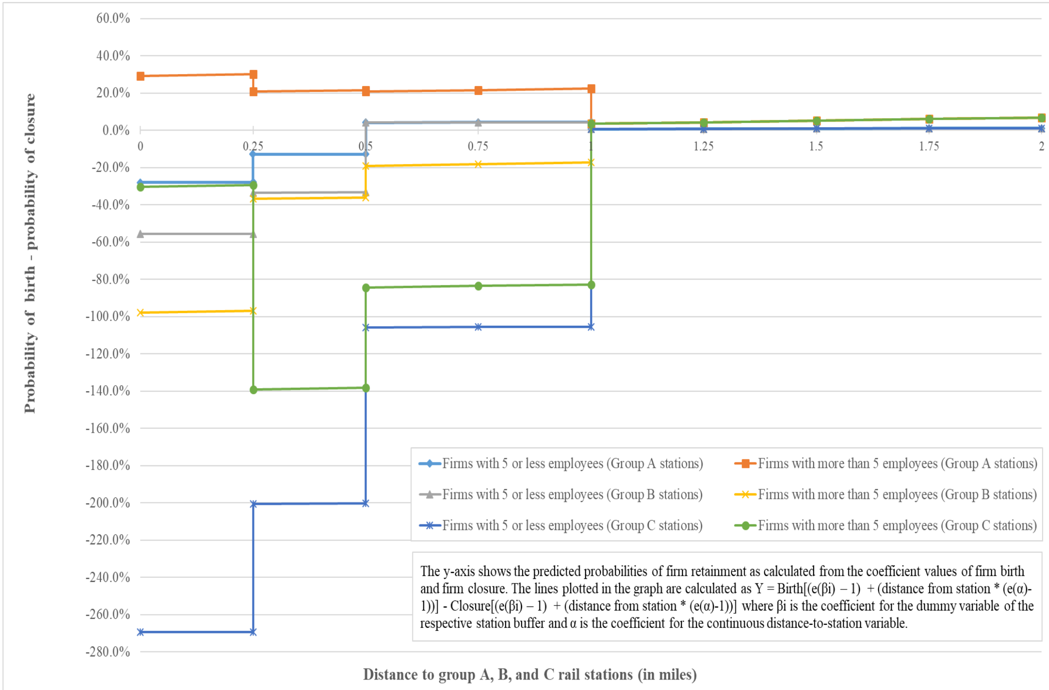

Figure 3. Probability of firm retention of station distance variables by firm size

On the other hand, areas near rail stations opened after 1990 (Group B and C stations) exhibit negative probability of firm retention compared to areas further away from the stations (see Figure 3). In Figure 3, the upward slope of the plotted line for firms with more than five employees indicates that the likelihood of firm retention increased between 1990 and 2010 in areas that are further in distance from the rail stations. These results overall show that rail stations have not consistently boosted firm retention nearby, except in the case of areas near the mature rail stations that were opened before 1990.

5 Discussions and concluding remarks

In the period between 1990 and 2010, there has been inconsistent growth in urban density near the passenger rail stations in the state of Maryland. The analysis results in this study suggest that areas near stations have belated positive economic impacts, shown by positive probabilities of firm retention around the mature rail stations that were opened before 1990. In comparison, areas near the less mature stations that were opened after 1990 had predominantly negative probabilities of firm retention, compared to the rest of the study area. There has been a lack of deliberate planning to encourage urban densification near rail stations, possibly combined with some regulations that may have actively discouraged densification near the stations in favor of continuous suburbanization.

The inconsistency in firm retention near rail stations raises the question of what policymakers should do differently to encourage transit-oriented development. After all, the densification of station areas (implied by positive firm retention) is what advocates of transit-oriented-development promote to bring about, including improved accessibility, reduced traffic congestion and air pollution due to modal shift, and increased walkability which accommodates more healthy and active lifestyles. However, areas near the stations do not experience economic gain in terms of an increase in firm density, at least in the short term, without proper policies and planning. For more immediate results, policymakers and planners advocating for transit-oriented development should be more initiative-taking in directing development near rail stations.

Future studies can take a step further when analyzing the connection between rail transit and firm dynamics with consideration of firm relocation, which is the third component of firm dynamics identified in the literature review, but not included in the analysis of this study. Another important aspect to address in future studies is the endogeneity of the location of rail stations. Rail lines and stations are often not randomly placed. They are rather placed in areas with pre-existing location-specific conditions to meet certain objectives, such as: (1) attracting higher ridership, (2) serving existing residential and job locations, and (3) stimulating economic development. Additionally, the types and functions of stations may vary based on the locations selected. Suburban stations often serve as a station to attract passengers who live in the suburbs and commute to another location along the rail line, including stations with park-and-ride facilities. Such suburban stations are not anticipated to contribute to the densification of firms unless particular planning objectives for TOD with firms are set up with a rail station development.

Lastly, the influence of station construction on business closures is another potential area for future research. Due to data limitations, it is difficult to accurately measure this complex issue, which reflects factors such as the nature of the business and the strategy of each firm. Our current model observes predominantly broader effects using distance to stations as a proxy.

Acknowledgments

Partial funding for open access provided by the University of Maryland Libraries' Open Access Publishing Fund.

References

Acs, Z. J., & Armington, C. (2006). *Entrepreneurship, geography, and American economic growth.* Cambridge, UK: Cambridge University Press.

Armington, C., & Acs, Z. (2002). The determinants of regional variation in new firm formation. *Regional Studies: The Journal of the Regional Studies Association, 36*(1), 33–45.

Audretsch, D. B, & Fritsch, M. (1994). The geography of firm births in Germany. *Regional Studies, 28*(4), 359–365.

Bacher, H. U., & Brulhart, M. (2013). Progressive taxes and firm births. *International Tax and Public Finance, 20*(1), 129–168.

Barnatchez, K., Crane, L., & Decker, R. (2017). *An assessment of the national establishment time series (NETS) database* (Finance and economics discussion series 2017-110). Washington, DC: Board of Governors of the Federal Reserve System.

Baum-Snow, N., & Kahn, M. (2000). Effects of urban rail transit expansions: Evidence from sixteen cities, 1970-2000. *Brookings-Wharton Papers on Urban Affairs*, *2005,* 147–206.

Bell, A, & Jones, K. (2015). Explaining fixed effects: Random effects modeling of time-series cross-sectional and panel data. *Political Science Research and Methods, 3*(1), 133–53.

Bernick, M., & Cervero, R.(1997). *Transit villages in the 21st century*. New York: McGraw-Hill.

Boarnet, M. G., & Crane, R. (2001). *Travel by design: The influence of urban form on travel.* Oxford, UK: Oxford University Press.

Bowes, D., & Ihlanfeldt, K. (2001). Identifying the impacts of rail transit stations on residential property values. *Journal of Urban Economics 50*(1), 1–25.

Browning, J. E. (1980). *How to select a business site: The executive's location guide*. Toronto: Mcgraw-Hill.

Cainelli, G., Montresor, S., & Marzetti, G. V. (2014). Spatial agglomeration and firm exit: A spatial dynamic analysis for Italian provinces. *Small Business Economics: An Entrepreneurship Journal, 43*(1), 213–228.

Capello, R. (2010a). Location regional growth and local development theories. *Aestimum, 58,* 1–25.

Capello, R. (2010b). Spatial spillovers and regional growth: A cognitive approach. *European Planning Studies, 18*(5), 653–675.

Cervero, R., & Duncan, M. (2002). Transit's value-added effects: Light and commuter rail services and commercial land values. *Transportation Research Record, 1805*, 8–15.

Chatman, D. G., & Noland, R. B. (2014). Transit service, Physical agglomeration and productivity in US metropolitan areas. *Urban Studies, 51*(5), 917–937.

Chatman, D. G., Noland, R. B., & Klein, N. (2016). Firm births, access to transit, and agglomeration in Portland, Oregon, and Dallas, Texas. *Transportation Research Record, 2598,* 201601.

Coughlin, C. C, & Segev, E. (2000). Location determinants of new foreign-owned manufacturing plants. *Journal of Regional Science, 40*(2), 323–351.

Giuliano, G. (2004). Land-use impacts of transportation investments: Highway and transit. In *The geography of urban transportation*. New York: Guilford Press.

Graham, D. J., & Gibbons, S. (2019). Quantifying wider economic impacts of agglomeration for transport appraisal: Existing evidence and future directions. *Economics of Transportation, 19,* 100121.

Graham, D. J., & Gibbons, S. (2019). Quantifying wider economic impacts of agglomeration for transport appraisal: Existing evidence and future directions. *Journal of Benefit-Cost Analysis, 10*(3), 375–400.

Hausman, J., Hall, B H., & Griliches, Z. (1984). Econometric models for count data with an application to the patents-R&D relationship. *Econometrica, 52*(4), 909–938.

Hess, D. B., & Almeida, T. M. (2007). Impact of proximity to light rail rapid transit on station-area property values in Buffalo, New York. *Urban Studies, 44*(5-6), 1041–1068.

Holl, A. (2006). A review of the firm-level role of transport infrastructure with implications for transport project evaluation. *Journal of Planning Literature, 21*(1), 3–14.

Holl, A. (2004a). Manufacturing location and impacts of road transport infrastructure: Empirical evidence from Spain. *Regional Science and Urban Economics, 34*(3), 341–363.

Holl, A. (2004b). Transport infrastructure, agglomeration economies, and firm birth: Empirical evidence from Portugal. *Journal of Regional Science, 44*(4), 693–712.

Holl, A. (2004c). Start-ups and relocations: Manufacturing plant location in Portugal. *Papers in Regional Science: The Journal of the Regional Science Association International, 83*(4), 649–668.

Johnson, P., & Parker, S. (1996). Spatial variations in the determinants and effects of firm births and deaths. *Regional Studies, 30*(7), 679–688.

Liu., C., Erdogan, S., Ma, T., & Ducca, M. (2016). How to increase rail ridership in Maryland: Direct ridership models for policy guidance. *Journal of Urban Planning and Development, 142*(4). https://doi.org/10.1061/(ASCE)UP.1943-5444.0000340

Katz, B., & Puentes, R. (2005.) *Taking the high road: A metropolitan agenda for transportation reform* (James A. Johnson metro series). Washington, DC: Brookings Institution Press.

Mathur, S., & Ferrell, C. (2009). *Effect of suburban transit oriented development on residential property values.* San Jose, CA: Mineta Transportation Institute.

McDonald, J. F. (2007). *Urban economics and real estate: Theory and policy*. Malden, IA: Blackwell Publishing.

Melo, P. C, Graham, D. J., & Brage-Ardao, R. (2013). The productivity of transport infrastructure investment: A meta-analysis of empirical evidence. *Regional Science and Urban Economics, 43*(5), 695–706.

Melo, P. C., Graham, D. J., & Noland., R. B. (2010). Impact of transport infrastructure on firm formation: Evidence from Portuguese municipalities. *Transportation Research Record: Journal of the Transportation Research Board, 2163*, 133–143.

MTA. (2015). Purple Line preliminary economic impact study.

Nelson, A. C., Eskic, D., Ganning, J. P., Hamidid, S., H., & Petheram, S. J., Liu, S. J., & Ewing, R. (2015). Office rent premiums with respect to distance from light rail transit stations in Dallas and Denver. *Urban Studies and Planning Faculty Publications and Presentations, 128*.

Newman, P., & Kenworthy, J. R. (1999). *Sustainability and cities: Overcoming automobile dependence.* Washington, DC: Island Press.

Pan, Q. (2013). The impacts of an urban light rail system on residential property values: A case study of the Houston metrorail transit line. *Transportation Planning and Technology, 36*(2), 145–146.

Ray. R. (2017). Open for business? Effects of Los Angeles metro rail construction on adjacent businesses. *Journal of Transport and Land Use, 10*(1), 725–742

Reynolds, P. (1994). Autonomous firm dynamics and economic growth in the United States, 1986–1990. *Regional Studies, 28*(4), 429–442.

Risselada, A., Schutjens, V., & Van Oort, F. (2013). Real estate determinants of firm relocation in urban residential neighborhoods. *Tijdschrift Voor Economische En Sociale Geografie, 104*(2), 136–158.

Schuetz, J. (2015). Do rail transit stations encourage neighborhood retail activity? *Urban Studies, 52*(14), 2613–2634.

Schumpeter, J. (1934). *The theory of economic development.* Cambridge, MA: Harvard University Press.

Smith, Jr., D. F., & Florida, R. (1994). Agglomeration and Industrial Location: An econometric analysis of Japanese-affiliated manufacturing establishments in automotive-related industries. *Journal of Urban Economics, 36*(1), 23–41.

Sutaria, V., & Hicks., D. A. (2004). New firm formation: Dynamics and determinants. *The Annals of Regional Science: An International Journal of Urban, Regional and Environmental Research and Policy, 38*(2), 241–262.

U.S. Bureau of Economic Analysis. (2023). Gross domestic product by metropolitan area, 2001-2010. Retrieved from https://www.bea.gov/data/gdp/gdp-metropolitan-area

U.S. Environmental Protection Agency. (2018). *Smart location database.* Retrieved from https://www.epa.gov/smartgrowth/smart-location-mapping#SLD

Walls, D. (2008). *Understanding data in the NETS database.* NETS Documentation.

Yu, H., Jiao, J., Houston, E., & Peng, Z.-R. (2018). Evaluating the relationship between rail transit and industrial agglomeration: An observation from the Dallas-Fort Worth region, TX. *Journal of Transport Geography, 67,* 33–52.