Does Built Environment Matter for Innovation?

A quantitative Study of the Physical Assets of Innovation Districts in the United States

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Abstract

A growing number of leaders, policy makers, developers, city influencers, and researchers are working on unleashing the concealed economic potential of cities. "Innovation District" is a recent urban model that has emerged as the result of the U.S. economy's transformation from traditional industrial economies to the knowledge-intensive. The distinguished built environment characteristics of "Innovation Districts" are density, walkability, land use mix, and enhanced transit accessibility. They are identified as the contributors to the innovation-driven economic prosperity through business clustering, creative economy, and regional economic resiliency. A large body of theoretical and qualitative studies have sought to shed a light on the concept of Innovation District. There is, however, a lack of quantitative evidence that support these studies. This national study seeks to fulfill this gap in the literature and examine the relationship between the built environmental characteristics, such as walkability, transit quality and urban form, and innovation generation at the neighborhood level. We used Multi-level Modeling (MLM) to account for the built environment characteristics at both neighborhood and regional levels. Accounting for economic and socio-demographic cofounding variables, we found that innovative firms tend to locate more in dense, pedestrian-friendly, and transit accessible neighborhoods. We also found that a typical neighborhood in a compact region is more attractive for innovative firms than a sprawling region. Our findings confirm the significance of urban form and its physical features on the notion of Innovation Districts theorized by previous studies.

Keywords: Innovation District, built environment, public transit, urban sprawl, compactness, pedestrian-friendly

Introduction

During the final day of 2016 Democratic National Convention Hillary Clinton committed to robust U.S. economy through enhancing innovation, small businesses, and technology during the first 100 days of her possible administration (1). It is evident that the U.S. economy relies more and more on innovation and cities; particularly toward the rise of “innovation districts”. Innovation districts are compact, mixed-use, walkable, and transit accessible districts with leading-edge educational institutions and talented human capital and, as a result, are where the innovation generation is accelerated (2). The California’s Silicon Valley and Boston’s Route 128 Technology Corridor are successful examples of how built environment could enhance innovation in the urban settings.

The emergence of innovation districts is a result of transformation of traditional economy to the modern knowledge economy. The traditional economy used to rely on factories, mass manufacturers and an intensive labor force while the creative economy relies heavily on the entrepreneurs, educational institutions, innovative businesses, and talented human capital (3). This transformation, at least in theory and to some extent in practice, has made significant implications and changes in the structure of urban areas (4) The notion of “industrial districts” where the goal was to provide working and living places for the greater number of workers has changed to the notion of innovation districts where the goal is to provide quality work and life experience for the creative class (5).

Several researchers sought to understand the characteristics of innovation districts (2, 6, 7, 3). Some studies focused on the built environmental preferences of the creative class as talented human capital (7, 8). Others applied foundational urban economic theories which focuses on the business clustering and business location decision making (9, 10). The majority of these studies are theoretical and qualitative in nature. There is a lack of quantitative, data-based evidence that support these theories and show how built environment at both neighborhood and regional scales influence innovation generation in an urban setting.

This national study aims to address this gap by examining the relationship between built environment characteristics and innovation generation. Using Multi-level Linear Modeling (HLM), we account for the built environment characteristics at both neighborhood and regional levels. The major built environment characteristics at the neighborhood level are the degree of mixed-use, walkability, transit availability/quality, and street accessibility. We account for urban form at the regional scale through the degree of urban sprawl as a proxy for regional accessibility.

This study employs disaggregated data of innovation generation from the Small Business Innovation Research (SBIR) program coordinated by the Small Business Administration (SBA). The SBIR program has been awarding the competitive federal grants to the innovative small businesses since 1982 (11). Our study covers a Fifteen-year timeframe and includes all the SBIR awarded firms from 2000 to 2015. One great advantage of using SBIR over other databases is the fact that it is designed to support small businesses which otherwise could not compete with large firms such as Google and Apple. We gathered neighborhood level data from various data sources and we used the widely cited Ewing and Hamidi (2014) metropolitan compactness index for the measure of urban compactness.

The Rise of Innovation Districts

The emergence of innovation districts is the result of several leading and historical trends. First, business clustering and geographic proximity play a significant role. Jacobs (1970), and more recently Katz and Bradley (2013) describe the necessity of spatial proximity for industries, businesses and universities in order to have access to human capital and flow of knowledge with lesser marginal costs (12, 4).

The other significant contributor to the emergence of innovation districts is the change in the American family structure and preferences. Traditionally, the isolation of work and life was the preference of a typical American household living in suburban areas. Residential preferences has changed substantially in recent years as a result of socio-demographic shifts such as delayed marriage, fewer number of children in the family and a smaller household size which has led to an increasing preference for living in compact and walkable neighborhoods (13). Previous studies show an increasing trend in the number of people who live within three miles of the central business district (14, 15). The preference for walkable distance to restaurants, retail, cultural, and educational institutions is even greater for the creative and educated class (8). Walkability is also recognized as an important factor for college-educated millennials when they choose a place to live and work after graduation (15).

An educated working class and creative human capital are the generators of knowledge economies (7). High-tech firms and businesses follow the knowledge workers and so they tend to relocate to denser, more compact and accessible urban areas (16). Therefore, the areas that offer appealing living environment for them, are more successful in attracting the knowledge intensive companies which in turn results in higher innovative activities and more economic prosperity. Detroit MI, Houston TX, and Buffalo NY are examples of cities have sought to incorporate the concept of innovation district in their future plans (17, 4). Some regions such as Boston have already started to implement the concept of innovation through the Boston's Route 128 Technology Corridor (18).

Characteristics of the Innovation Districts

Innovation districts are compact, transit-accessible areas that provide a mix of housing, offices, and retail. Innovation districts bring together leading-edge research institutions and high-tech companies and connect them to start-ups, business incubators, and accelerators (2). As a result, innovation districts facilitate innovation generation through creating, attracting, and retaining the creative class and knowledge-intensive companies (3, 19). So the question is why some places support innovation generation more than others. What locational factors contribute to more innovation in these places?

In 2014 the Brookings Institution released a comprehensive, and the first of its-kind report, on the Innovation Districts (2). According to this report, Innovation Districts have three categories of assets: economic assets, networking assets and physical assets.

Economic assets are referred to as the presence of 3 general business categories. The first category includes the innovation drivers functioning as universities, anchor institutions, high tech research-oriented businesses (such as material science, energy technology and nanotechnology), creative firms (like art-tech companies), and small artisan manufacturing or textile production. The second category presents to support the growth and innovative activity of the first category serving as incubators, start-ups, accelerates, etc. The third category includes the businesses that build the neighborhood sense of an innovation district like cafes, restaurants, grocery stores, bars, local retails and hotels. The economic assets emphasize the importance of spatial proximity and clustering of economic activities.

Networking assets concentrate on the long been acknowledged value of networking through competition, collaboration, and learning between companies (20). These assets consist of strong ties and weak ties. The strong ties enhance the contact and communication between actors of similar fields and by this nature are workshops, training sessions, conferences, and industry specific blogs for specific fields. The weak ties tend to either build new or enhance existing cross-sector relationships. Weak ties emerge in form of innovation centers, city halls, hackathons, and the training sessions that aim to help businesses grow. The networking assets emphasize the importance of social interaction, which provides the chance of serendipitous encounters, networking, and knowledge spillover.

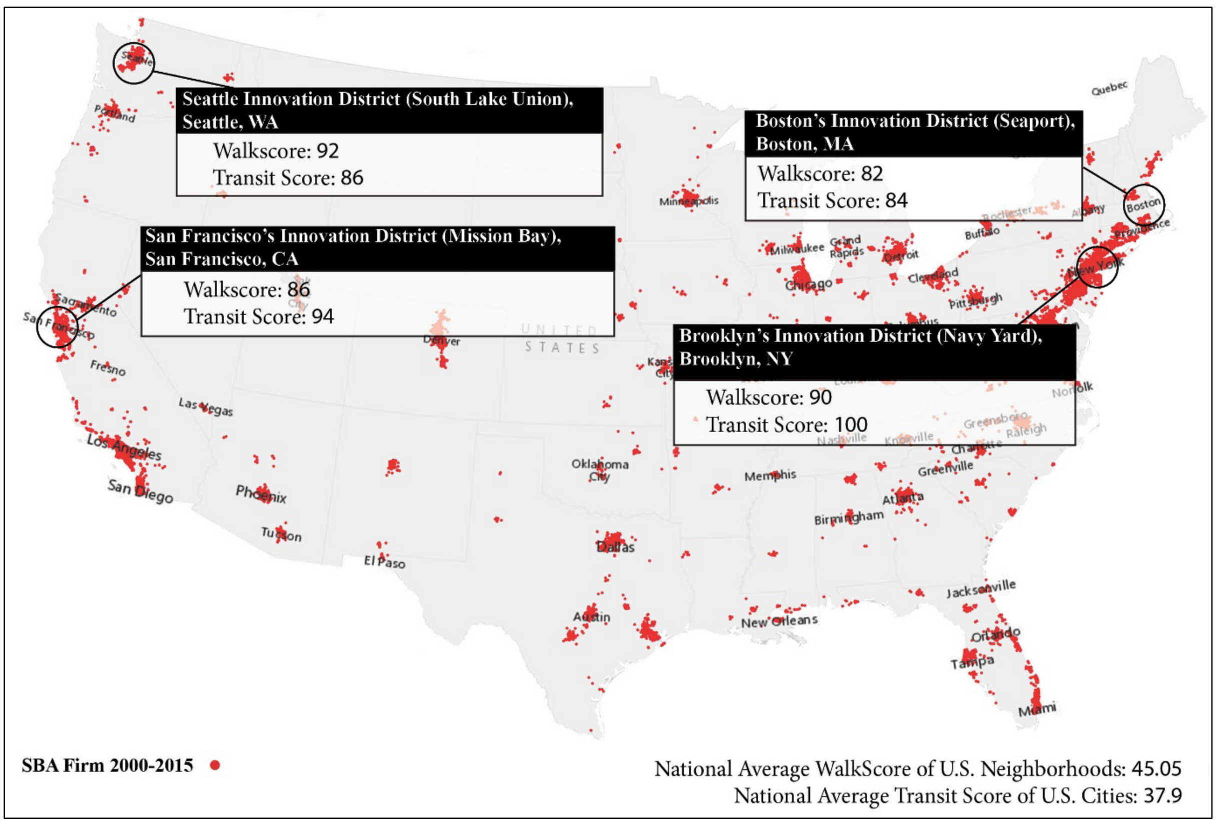

FIGURE 1 Selective Physical Assets of Four Innovation Districts and Their Comparison to the National Average (Source: Authors)

The innovation districts' physical assets enhance the innovative ecosystem through providing density, high level of mix use and street connectivity. They include three categories of built environmental characteristics. The first category belongs to the public realm and includes the neighborhood-scale public spaces such as neighborhood parks, exhibitions, concert areas, plazas and public realm's eateries which will strengthen the social interactions. To get the most and best out of quality public spaces, they need to be integrated within a dense and highly mixed-use development.

The second category has to do with the preferences of the innovation demographics. They prefer the micro/mixed income housings built in the mixed-use and dense complexes of houses, offices, co-working areas and stores. Connectivity of the public realm's and private realm's physical assets is considered within the third category. The third category is the walkable and bikable street network with the enhanced street crossings. By the same notion, high quality and accessible public transit serves both internal and regional connectivity. Boston's Silver Line, Houston's Red Line, and the future Detroit's M-1 line are the transportation infrastructure contributors to the development of innovation districts in each of these cities.

Regional Accessibility and Innovation

Proximity, or in a broader term "accessibility," of industries, business services, and anchor institutions is a driving force for innovation (21, 22, 23, 24, 25). Accessibility provides networking opportunities for these entities through raising interactions, collaborations, and knowledge spillover (26). Compact areas with stronger transportation accessibility foster networking opportunities between people via enhancement of social capital (27). In contrast, urban sprawl could provide less opportunity for knowledge flow and interaction between innovative people, which in turn could result in lesser innovation and knowledge production.

Metropolitan Sprawl is characterized in the literature as areas with poor accessibility. In scattered or leapfrog development, residents and service providers must pass vacant land on their way from one developed use to another. In commercial strip development, the consumer must pass other uses on the way from one store to the next — the antithesis of multipurpose travel to an activity center. Of course, in low-density and single-use development, everything is far apart because of large, private land holdings and segregation of land uses. In sprawl, poor accessibility of land uses to one another may leave residents with no alternative to miles and miles of automobile travel. So the question is how poor accessibility might affect regional innovative capacity.

There is little evidence in the literature on how built environmental attributes and the resulting accessibility influence innovation generation at different geographic scales. This study seeks to address these gaps by employing multilevel modeling and gathering data from various sources at the neighborhood and regional levels. In the next section, we will explain data, variables and the methodology.

Methods

Data and Variables

The complete set of variables and data sources are shown in Table 1. Our dependent variable is the number of innovative businesses in each census tract are obtained from SBA. The SBIR database is one of the most widely used measures of innovation capacity under the innovation counts category (28, 29). SBA serves as the coordinating agency for two national innovative award programs: SBIR and Small Business Technology Transfer (STTR). Both recognize innovative activities accomplished by small businesses. SBIR awards are given to innovations developed solely by small businesses, while STTR awards are given to collaborative innovative activities between small businesses and research institutions. SBIR and STTR awards are granted in three phases.

- Phase I recognizes innovative concepts from small businesses. At this phase, the feasibility of idea and proof of concept are assessed.
- Phase II covers the full research and development for a prototype among Phase I grantees.
- Phase III is the commercialization phase. Phase I/II grantee products, services, technologies, or processes are produced and delivered (11).

In this study, we use the SBIR and STTR database as our measure of innovation capacity. In comparison to other measures, the SBIR and STTR database is inclusive and does not favor large companies as the R&D database does. Also, it evaluates and recognizes innovation for both process and product through a competitive three-phase assessment method from proof of concept to development and commercialization. Finally, the chance of overestimation of innovation is less than other approaches, and it introduces the more valuable innovations market wide.

Our study includes both SBIR and STTR phase II between 2000 and 2015. SBA provides a substantial award in phase II to research and development of an innovation. The fifteen year time frame allows us to obtain a consistent measure of innovative firms than relying on single-year data. We used walk score as the measure of walkability at the neighborhood level.

TABLE 1 Data and Variables

Variables		Data Sources
Level 1 Dependent variable		
SBA_Firms	Number of SBIR/STTR Phase II firms between 2000-2015	SBA 2016
Level 1 Independent variables (census tract level)		
pctWrk	Percentage of working age population for 2010	Census 2010
htechcap	Average number of high tech jobs per capita	LED 2011
WlkScr	Census tract level Walk Score	Walk Score Inc. (2010)
Transfreq	Average transit service frequency	SLD-EPA (2010)
Entropy	Land use mix within a census tract (entropy index based on net acreage in different land use categories that ranges from 0, where all developed land is in one use, to 1, where developed land is evenly divided among uses)	Computed in the study using 2010 LEHD data
Actden	Activity density (sum of population and employment divided by gross land area in square miles)	Computed in the study using 2010 LEHD and census data
intden	Intersection density	Computed using TomTom 2007 database
hhincome	Average household income	ACS 2007-2011
Pop000	Census tract population in 1000s	Census 2010
Level 2 Independent Variables (metropolitan level)		
MSAindex	metropolitan compactness index for 2010	Ewing and Hamidi (2014)
Crime	violent crime rate per 100,000 population	FBI Uniform Crime Statistics 2010
UniR&D	The university R&D expenditure 2011	NSF

Our first built environment variable is census tract level Walk Score. It was computed using data from Walk Score, Inc. to measure proximity to amenities, with different amenities weighted differently and amenities discounted as the distance to them increases up to one mile and a half, where they are assumed to be no longer accessible on foot.[1]

We accounted for transit availability and quality through the transit service frequency data retrieved from Smart Location Database (SLD) developed by Environmental Protection Agency (EPA). Transit service frequency dataset is calculated based on the average number of scheduled transit service per hour during the evening peak period (4:00-7:00 pm on a weekday) for all block groups in the U.S. we aggregated up the block group data and computed this variable at the census tract level.

Other neighborhood level built environmental variables used in our model are activity density, land-use mix and intersection density. Intersections are where street connections are made and cars must stop to allow pedestrians to cross. The higher the intersection density, the more walkable the city (30). Intersection density has become the most common metric in studies of built environmental impacts on individual travel behavior (31). Our land use mix variable, an entropy measure, equals 1 for block groups with equal numbers of jobs in each sector; 0 for block groups with all jobs in a single sector within the ring; and intermediate values for intermediate cases. The sectors considered in this case were retail, entertainment, health, education, and personal services.

At the regional level, we used the metropolitan compactness index developed by Hamidi and Ewing (2015). The metropolitan compactness indices consist of 21 built environment variables of four distinct dimensions: development density, land-use mix, population and employment centering, and street connectivity. The indices were constructed so that the more compact a metropolitan area was, the larger its index value.

At the MSA level, we also controlled for the R&D of high-tech industries, university R&D expenditure, and crime rate. We employed the 2011 Longitudinal Employer-Household Dynamics (LEHD) from the U.S. Census Bureau, which is based on North American Industry Classification System (NAICS) codes for the R&D of high-tech sectors. The R&D of high-tech companies is computed as the proportion of high-tech jobs to population. Suggested by the literature, we included two high-tech sectors 1) mining, quarrying, and oil and gas extraction and 2) manufacturing industries. We used Standard Industrial Classification (SIC) codes of 28, 35, and 36 as high-tech employment sectors (32) and converted them into NAICS.

As for the university R&D expenditure, we gathered data from the publicly available 2011 National Science Foundation Business Research and Development and Innovation Survey. Using Geographic Information System (GIS), we aggregated and computed the university R&D expenditure at the MSA level.

Analytical model

As shown in table 1, the data used in this analysis have a “nested” structure and should be analyzed accordingly. Since the census tracts located in an MSA share the characteristics of that

[1] A grocery store, for example, gets three times the weight of a book score. The distance decay function starts with a value of 100 and decays to 75 percent at a half mile, 12.5 percent at one mile, and zero at 1.5 miles.

MSA, such as the metropolitan compactness index, and could not be treated as independent of each other. The nesting feature causes the dependence among cases, violating the independence assumption of OLS regression. In this situation, the standard errors of regression coefficients associated with MSA characteristics based on OLS will then be underestimated, and regression coefficient themselves will be inefficient (33).

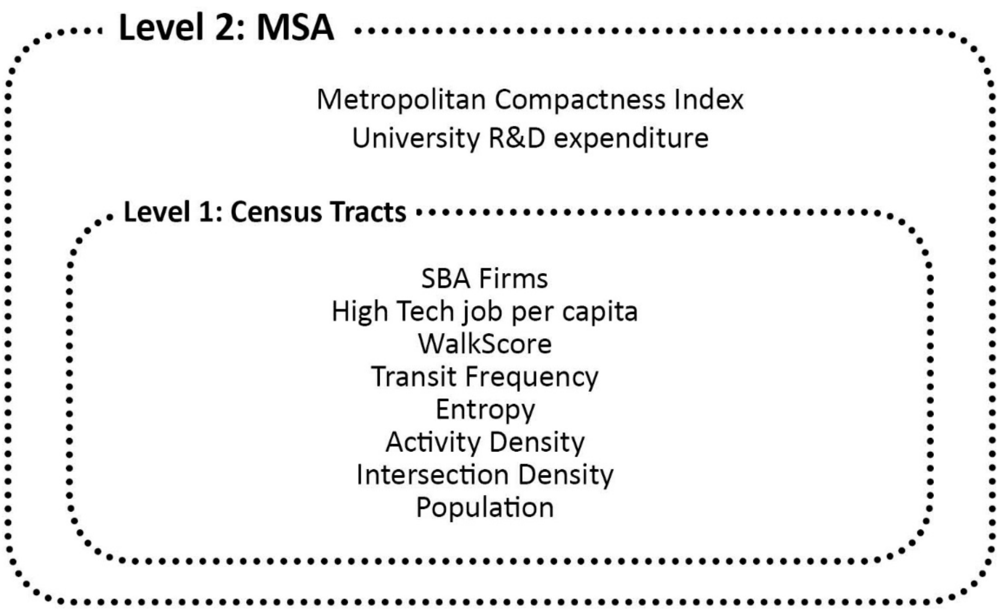

FIGURE 2 Conceptual Framework Showing the Nesting Structure of Variables

Multilevel Modeling (MLM) addresses the issue of nesting structure and dependence among cases and leads to more accurate coefficient and standard error estimates. In this analysis, the numbers of innovative firm were regressed on neighborhood characteristics in level-1 models. The intercepts and coefficients of level-1 models were regressed on regional characteristics in level-2 models. Initially, we estimated two different models. In the first model, only the intercept was allowed to randomly vary across respondents, while all of the regression coefficients were treated as fixed. These are referred to as “random intercept” models. Later on, regression coefficients were allowed to randomly vary across higher level units as well, and interactions between levels were allowed. These are called “random coefficient” models. As cross level interaction terms seldom proved significant, we reverted to the random intercept model. Only this model are presented in the next section.

The other statistical complication relates to our dependent variable. Our dependent variable is the number of innovative firms (count data) in a census tract which is a count. Two basic methods of analysis are available when the dependent variable is a count, with nonnegative integer values, many small values and few large ones. The methods are Poisson regression and negative binomial regression. The two models differ in their assumptions about the distribution of the dependent variable. Poisson regression is appropriate when the dependent variable is equidispersed, meaning the variance of counts is equal to the mean. Negative binomial regression is appropriate when the dependent variable is overdispersed, meaning that the variance of counts is greater than the mean. Popular indicators of overdispersion are the Pearson and $\chi 2$ statistics divided by the degrees of freedom, so-called dispersion statistics. If these statistics are greater than 1.0, a model is said to be overdispersed (34). By these measures, we have overdispersion of innovative firm counts in our dataset, and the negative binomial model is more appropriate than the Poisson model. Therefore we employed negative binomial multi-level modeling in this study.

Results and Discussion

We estimated a multi-level negative binomial model using HLM 6.8. The results of the best fitted model is presented in Table 2. The coefficients of most variables are significant and have the expected signs.

Our findings support the notion of "innovation districts". According to the literature, the innovation districts thrive where housing, restaurants, retails, anchor institutions and small-scale innovative activities are collocated near transit (2). We find that the number of innovative firms in a census tract is positively and significantly associated with walkScore, transit frequency and activity density although in case of activity density it approaches the significance level at 0.1. The most significant variable in the model is WalkScore which confirms the importance of walkability on innovation generation. Also, neighborhoods that enjoy access to a quality transit service are more attractive for innovative small firms.

Our results confirm that innovative firms are more likely to locate in mixed-use neighborhoods where there is a mix of retail, entertainment, health, education and other major destinations are, although the relationship is not significant. We found a significant negative relationship between the intersection density and the number of innovative firms in a census tract. More intersections mean more stops and slower traffic flow (35) which could be unpleasant to firms, innovative businesses and commuting employees.

TABLE 2 Negative Binomial Reression Analysis of Innovation Generation, Buit Environment and Transportaion Accessiblity for Urban Cesus Tracts

	Coeff.	Std. error	t-ratio	p-value
Constant	-0.233	0.455	-0.512	0.610
htechcap	0.838	0.234	3.581	0.001
WlkScr	0.00964	0.0016	6.116	0.000
Transfreq	0.000553	0.000225	2.464	0.014
Entropy	0.033	0.172	0.191	0.848
Actden	0.000004	0.000002	1.690	0.091
intden	-0.0053	0.001	-5.166	<0.001
Pop000	0.00555	.0041	1.353	0.176
MSAindex	0.0065	0.0024	2.688	0.009
lnuniR&D	.026	.0275	0.942	0.350
Pseudo-R^2	0.517			

At the MSA level, we found that the number of innovative firms in a census tract is positively and significantly associated with the MSA level of compactness. In other words, a typical census tract in a compact metropolitan area is more attractive for innovative firms than the same census tract in a sprawling metropolitan area. This result squares with our expectations based on previous studies and evidence (7, 21, 25, 23). Sprawling areas are heavily car dependent, do not accommodate regional accessibility and reduce opportunities for social life which could inspire the creative class to socialize and exchange ideas (7, 4, 2, 3). Compact places increase the chance of serendipitous encounters, networking, and knowledge spillover (36, 2).

Our model suggests a positive but insignificant relationship between the university R&D expenditure at the regional scale and the number of neighborhood level innovative firms. Less than 10 percent of SBA awards between 2000 and 2015 were allocated to the university-businesses collaboration innovation. Thus, the collaboration between high-tech industries, particularly small businesses, and universities needs further studies.

All our control variables have the positive sign in this model, but they are not always significant. The size of a census tract does not significantly affect its likelihood of having higher number of innovative firms. Number of high-tech firms in a neighborhood is positively and significantly associated with the number of innovative firms. This agrees with the theory of spatial proximity of high-tech firms as the main contributor to the innovation. The industry R&D and regional crime rate are the other two insignificant variables.

The result of this study represents the significance of the three categories of physical assets as the key components the innovation district (2). Both public realm and privately built physical assets result in the development of an innovative ecosystem when are highly land use mix and dense. The innovative ecosystems at the neighborhood level will generate more innovation when they are not isolated. Our findings confirm the significance of both enhanced internal connectivity through walkability, and an effective external connectivity to broader opportunities in the region through public transit for creating an innovative ecosystem that supports innovation generation.

Furthermore, the creative class would prefer to live in places that are dense and mixed-use and offer opportunities for walking, biking, and transit use. The creative class is the driver for regional innovation and places that offer appealing living environment for them, are more successful in attracting them and knowledge intensive companies which, in turn, results in higher innovative activities and more economic prosperity.

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