TRANSIT, WALKABILITY, AND ECONOMIC DEVELOPMENT IN THE 21ST CENTURY: EXPLORATIONS FROM THE U.S. SPECIALIZED HIGH-TECH ZONES, PIVOTAL INDUSTRIES, AND INNOVATIVE SMALL BUSINESSES

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ABSTRACT:

TRANSIT, WALKABILITY, AND ECONOMIC DEVELOPMENT IN THE 21ST CENTURY: EXPLORATIONS FROM THE U.S. SPECIALIZED HIGH-TECH ZONES, PIVOTAL INDUSTRIES, AND INNOVATIVE SMALL BUSINESSES

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The economy in the 21st century has expanded the depth of creativity, speed, and flexibility in production, high-tech industry, and innovation. Hence, the new economic norm and high dependency on innovation and creativity require educated, talented, and specialized human capital, as well as proximity to research centers and universities. Furthermore, this new knowledge economy has also favored urban spaces that support spontaneous face-to-face encounters and knowledge exchange while appealing to the talented human capital. Besides these specific urban spaces, the transportation infrastructures could have a principle role in the new economy whether through fostering local, regional, or global accessibility to the talent, labor and customer markets, or for logistics purposes. While these economic impacts of transportation infrastructures and urban space are principal in the policy developments, they are less explored via quantitative analyses.

Historically, the economic outcomes of transportation systems gained attention in location theories, which provide the foundational framework for thinking about locational behavior of businesses with respect to their accessibility demands. While ample empirical studies addressed

classical location theories and the traditional economy, there is a lack of empirical studies, with respect to the knowledge economy. Particularly, with respect to transit and walking amenities, the existing empirical literature lacks enough attempts that look beyond real estate premiums and focus on other economic outcomes, such as employment, innovation productivity, or business performance, particularly in a knowledge and creative economy. Despite this gap in the empirical literature, theoretical attempts confer the dynamics through which such impacts can be unleashed. For instance, knowledge-based, creative, or high-tech businesses are theorized to concentrate at the top of the urban hierarchy being the most accessible neighborhoods and cities. Therefore, location decisions of such businesses would depend on proximity to major transportation hubs, such as regional airports, railways, or transit stations. While roadway networks could provide regional accessibility to employment sub-centers and long-distance freight mobility for high-volume manufacturing productions, transit and walking amenities could better benefit knowledge-based and creative industries. Additionally, Transit-Oriented Developments (TODs)-—as compact neighborhoods centered on transit stations with an efficient level of land use diversity, density, street connectivity, and walkability—likely play a key role in agglomeration dynamics and, hence, can lead to an increase in economic productivity. These built attributes can spur many agglomeration externalities-such as knowledge exchange, access to thick and specialized labor pools, and suppliers-there exists uncertainty between policy makers, business owners, investors, and developers about the positive impact of transit and walking amenities. Despite existing theoretical studies, there still exist multiple gaps in the literature. First, it is still unclear whether the above-mentioned dynamics have the same impact for knowledge-based firms, particularly with respect to tech sectoral differences. Second, there remains less than conclusive evidence tying place-based characteristics of TODs with creative and knowledge-based firm productivity. The investors, business owners, and policy makers are cautious to invest in TODs due to extensive existing literature that shows that increased property values in tandem with institutional and financial barriers impede TOD developments. Hence, a major contribution to the literature, decisions and policies about infrastructures is to provide further empirical insights about the location behaviors of knowledge and creative economy businesses; however, these categories include a broader list of industrial sectors with potential differences. Therefore, another gap in the literature has to do with the role of high-tech sectoral differences on transportation infrastructure needs. Studies on the accessibility needs of high-tech firms tends to draw on assumptions emerging out of agglomeration and placemaking frameworks and emphasize the expansion of transit services and enhancing walkability. However, industries impacted by the new logistic revolution, land values, easy access to the global e-economy, and the rise of online workers could prefer stronger highway systems. To address this gap, there is a need for more in-depth analyses of firm location behavior in different industrial sub-categories of knowledge economy.

In this dissertation, I address these gaps in three essays. In the first essay, the analysis uncovers the mechanism and the extent to which transit and walkability play role in a knowledge economy. The results from the second essay demonstrate whether the knowledge-based and creative firms in TODs have higher productivity. Lastly, the third essay identifies the location of specialized high-tech zones in the U.S., their sectoral typologies and examining the location behavior of different high-tech specializations with respect to transit and walkability in these zones.

By including more than five different analyses and the indicators for four modes of transportation, this dissertation aims to cover a diverse range of critical questions about the knowledge-based economic implications of transportation infrastructures. Additionally, using the address-level datasets on the location of knowledge-based and creative businesses, as well as innovations in the U.S., contributes to the validity of my results by increasing the sample size. Drawing upon disaggregated national datasets, this dissertation stands among the first attempts to provide empirical insights at the national level. The results of this dissertation will benefit a diverse audience, including members of academia and the policy development arena, as well as developers, business owners, and stakeholders.

My results uncover diverse impacts of transit and walking amenities in the new economy. First, I found that transit service quality and walkability contribute to a robust local knowledge economy through knowledge-based firms and the creative class, but they have an adverse relationship to the innovation production of STEM small firms. Additionally, I found that the knowledge and creative economy firms located in dense, mixed use, and walkable TODs with higher levels of activity experience 2.5 times increased sales on average. Lastly, when it comes to break down of high-tech industries to its subcategories, my results partially support the dominant narrative regarding the preference of knowledge-based industries for dense, walkable, mixed use, transit accessible areas. For instance, I found large numbers of high-tech firms in the IT and aerospace industries still attracted to peripheral, auto-centric spaces, which are at odds with sustainable transportation policies.

While in general I found that transit and walking amenities have a critical role in the new economy, policy developments they need to take consideration of the findings from this dissertation. For instance, I found that walkability and transit access could increase property values, and these features might make locations unaffordable for small innovative firms. Hence, findings on the impacts of walkability and transit access on innovation productivity in vulnerable small firms call for attention to equity aspects of innovation-supportive urban developments. Nevertheless, considering the findings on the increased productivity of the knowledge and creative economy firms in TODs, in the knowledge-based urban development policies TOD and knowledge-based economic development strategies should be planned in tandem in order to maximize outcomes. While seeking growth through attracting high-tech firms has emerged as a common trend among local policy leaders, they may want to revisit their growth strategies with respect to my finding about the different accessibility needs of high-tech industries to not only succeed in growing their knowledge economy, but also to secure sustainability goals.

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Chapter 1: INTRODUCTION

Economic Development in the 21st Century

The rise of the knowledge-based economy is perhaps one of the most important events of the 1970's, which increasingly relies on the role of knowledge-based businesses and innovation for the economic growth (Shearmur 2012). In this new economy, mass-production, (Fordism) driven by monopolistic manufacturing firms, is substituted with creativity, speed, and flexibility in production which requires high-tech based sectors and innovation (K. N. Credit 2018). Transformation to the knowledge economy has brought new production hubs, business needs, and labor and customer markets (Zandiatashbar and Hamidi 2018). Also, flexible and specialized production, just-in-time delivery, and global customers have led to footloose business location behavior (Audirac 2005; K. N. Credit 2018). Hence, the new economic norm and high dependency on innovation and creativity require educated, talented, and specialized human capital, as well as proximity to research centers and universities (Florida 2002a; L. F. Katz and Krueger 2016). Furthermore, this new knowledge economy has also favored urban spaces that support spontaneous face-to-face encounters and knowledge exchange while appealing to the talented human capital (Florida 2002a). Besides these specific urban spaces, the transportation infrastructures could have a principle role in the new economy whether through fostering local, regional, or global accessibility to the talent, labor and customer markets, or for logistics purposes (Chatman, Noland, and Klein 2016; K. N. Credit 2018; Maggioni 2002; Zandiatashbar and Hamidi 2018).. While these economic impacts of transportation infrastructures and urban space are principal in the policy developments, they are less explored via empirical analyses.

Transportation and Economic Developments

Policy makers and academics have often sought to understand specific patterns of economic development related to transportation infrastructure. The overall conclusion from the empirical literature shows a positive relationship between regional economic growth and transportation infrastructure improvement (Chatman and Noland 2014; Ewing 2008; Graham 2007).

Historically, the economic outcomes of transportation systems gained attention in location theories, which provide the foundational framework for thinking about locational behavior of businesses with respect to their accessibility demands (Beckmann, 1972; K. N. Credit, 2018). From Von Thunen's agricultural land use theory, to Alonso's urban land uses, to Weber's cost distance and Central Place's demand-based industrial location theory, achieving the optimal tradeoff between land value and transportation costs has been a principle goal in spatial distribution of economic activities (Alonso 1964; Beckmann 1972; Weber 1929).

While ample empirical studies addressed classical location theories and the traditional economy, there is a lack of empirical studies, with respect to the knowledge economy. Particularly, with respect to transit and walking amenities, the existing empirical literature lacks enough attempts that look beyond real estate premiums and focus on other economic outcomes, such as employment, innovation productivity, or business performance, particularly in a knowledge and creative economy.

Economic Outcomes of Transit and Walkability

While the literature on the impact of transit stations on firm location and employment growth is striving, there is extensive existing literature on their impact on property values (Banister 2012). Several empirical studies confirm that station proximity increases property values (Hamidi, Kittrell, and Ewing 2016; Mohammad et al. 2013). This increased property value copes with development intensity, primarily when the transit service is frequent and reliable with supportive land use policies-in areas with high ongoing economic growth (Cervero, 1994; Cervero & Duncan, 2002; Knaap, Ding, & Hopkins, 2001; Knight & Trygg, 1977; Landis, Guhathakurta, & Zhang, 1994; Iinstein & CloIr, 2003). Unlike the literature on the economic impacts of transit, empirical research on the economic impacts of walkable built environment is thin. The few existing studies that evaluate the association between walkability and property values, generally confirm the premium for property value in walkable neighborhoods (Leinberger 2013; Leinberger and Alfonzo 2012; Pivo and Fisher 2011). The literature lacks enough empirical analyses that look beyond the real estate premiums and focus on other economic outcomes, such as employment, innovation productivity, or business performance, particularly in knowledge and creative economy.

While the literature lacks empirical studies that evaluate the impacts of transit and walking amenities on knowledge and creative economy, theoretical attempts to confer the dynamics through which such impacts can be unleashed. For instance, according to Christaller's Central Place Theory, knowledge-based, creative, or high-tech businesses produce high-order products.

Thus, these businesses are theorized to concentrate at the top of the urban hierarchy being the most accessible neighborhoods and cities. Therefore, location decisions of such businesses would depend on proximity to major transportation hubs, such as regional airports, railways, or transit stations. This helps Knowledge Intensive Business Services (KIBS) to be more accessible for a wider range of customers while obtaining a larger pool of skilled workers (Shearmur 2010). While roadway networks could provide regional accessibility to employment sub-centers and long-distance freight mobility for high-volume manufacturing productions, transit and walking amenities could better benefit knowledge-based and creative industries (Noland, Chatman, and Klein 2014).

Moreover, for major KIBS and Research and Development (R&D) industries, information is the critical supply, and therefore, a knowledge economy needs the educated class to obtain the information. This demand illustrates the significant role of human capital in a knowledge economy, which is the foundation for the rise of the amenity richness theory (Shearmur, 2012). Starting with Florida (2004), several scholars have discussed that knowledge intensive firms and the creative class are particularly drawn to cities, because of their preference for social and economic diversity, mixed land use, and access to urban amenities. Hence, the non-driving transportation options, such as transit and walkability that facilitate proximity to restaurants, retail, and cultural and educational institutions is the critical quality of life amenities that are theorized to support the robust knowledge economy (Florida, 2004).

Lastly, enhanced economic productivity through agglomeration dynamics is another framework that could confer the key role of active transportation infrastructures in knowledge economy (Credit, 2018). For instance, Transit-Oriented Developments (TODs)-—as compact neighborhoods centered on transit stations with an efficient level of land use diversity, density, street connectivity, and walkability—likely play a key role in agglomeration dynamics and, hence, can lead to an increase in economic productivity (Chatman & Noland, 2014; Credit, 2017; Noland et al., 2014). By attracting households, workers, and firms in close proximity to one another, TODs could increase both local diversity and the density of firms, enlarge access to suppliers, consumers and specialized labor markets, and reduce transportation costs and travel time (Chatman and Noland 2011). TODs also have further benefits by enabling efficient matching of jobs and skwells, leading to less employee turnover and termination rates (Credit

2017; Chatman et. al. 2016; Chatman and Noland 2014, 2011). The same conceptual framework could be applied to the potential impacts of TODs on knowledge-based economic productivity, although it has not been empirically investigated.

Another gap in the literature has to do with the role of high-tech sectoral differences on transportation infrastructure needs. In the other words, the extent to which walking and transit amenities could affect the knowledge economy might depend on industrial specializations (Audirac 2005). For instance, IT industries are becoming increasingly less place-based as the result of relying on the self-employed, part-time, and flextime workforce , while the new logistic revolution extends the demand for road and air mobility as a response to the need for fast processing and distribution of time-sensitive high-tech production and goods (Kasarda 2000) (Kasarda, 2000). On the other hand, aeroscience-tech firms might require larger land areas and closer proximity to airports, which are mostly available in suburban areas (Cohen 2000). To address this gap, there is a need for more in-depth analyses of firm location behavior in different industrial sub-categories of the knowledge economy.

Despite the extensive existing theoretical studies, empirical analysis of the abovementioned dynamics is still striving. Hence, while the transit and walking amenities can spur many agglomerative externalities-such as knowledge exchange, access to thick and specialized labor pool and supplier-there exists uncertainty between policy makers, business owners, investors and developers about the positive impact of transit and walking amenities. It is still unclear whether the above-mentioned dynamics have the same impact for knowledge-based firms, particularly with respect to tech sectoral differences. Additionally, there remains less than conclusive evidence tying place-based characteristics of TODs with creative and knowledge-based firm productivity. The investors, business owners, and policy makers are cautious to invest in TODs due to extensive existing literature that shows that increased property values in tandem with institutional and financial barriers impede TOD developments (Cervero 2004; Dumbaugh 2004).

In this dissertation, I aim to provide a series of analyses to address the aforementioned gaps in the form of three essays. In the first essay, the analysis uncovers the mechanism and the extent to which transit and walkability play role in a knowledge economy. The results from the second essay demonstrate whether the knowledge-based and creative firms in TODs have higher productivity. Lastly, the third essay identifies the location of specialized high-tech zones in the U.S., their sectoral typologies and examining the location behavior of different high-tech specializations with respect to transit and walkability in these zones.

By including more than five different analyses and the indicators for four modes of transportation, this dissertation aims to cover a diverse range of critical questions about the knowledge-based economic implications of transportation infrastructures. Additionally, using the address-level datasets on the location of knowledge-based and creative businesses, as well as innovations in the U.S., contributes to the validity of my results by increasing the sample size. Drawing upon disaggregated national datasets, this dissertation stands among the first attempts to provide empirical insights at the national level. The results of this dissertation will benefit a diverse audience, including members of academia and the policy development arena, as well as developers, business owners, and stakeholders.

Problem Statement

Since 2013, KIBS employed almost 10% of the U.S. employment and generated nearly 20% of the national GDP. Their share of the GDP is expected to increase to nearly 25% during the next two decades. KIBS are anticipated to generate a quarter of a dollar value of all goods and services and, as a result, will drive the health of U.S. economy (Muro and Liu 2017).

The transformation from the traditional manufacturing economy to the knowledge-based economy has affected several policy developments including the framework for assessing the economic impacts of transportation policies. Thus, further empirical evidence plays a key role in supporting the needs of associated policy developments. The literature on the economic impacts of transit and walking amenities is mostly limited to property values (Credit, 2018). However, with respect to employment size, business location, or productivity, there remains less than conclusive evidence tying transportation infrastructures with the robust knowledge economy. As a result, while the shift to a knowledge economy started over forty years ago (Harvey 1989), 1989), many cities are still struggling to make the transition. Much of these cities' difficulty has to do with costly and traditional infrastructure investments, such as freeways and suburban industrial districts, which cannot be easily transitioned to address new social and economic behavior (Harvey, 1989). In addition, there is little empirical evidence on the role of transportation infrastructures in the knowledge economy.

In theory, the new logistic revolution, the need for just-in-time delivery, land values, easy access to global e-economy, and the rise of online workers could change the dynamics of the accessibility needs of tech sectors and the demand for transit and walking amenities versus road and air mobility (Audirac 2005). There is a critical need for data-driven, empirical evidence to quantify these dynamics and demonstrate the impact of transportation on employment size, productivity, and location preferences of high-tech firms, since these industries will hold an increasing share in the GDP and of the U.S. employment (Muro and Liu 2017). Furthermore, the literature has yet to distinguish between different sectors of STEM based high-tech industries.

Research Objectives

Given the abovementioned gaps in the existing literature, the goal of this dissertation is to examine the extent to which transit accessible and walkable built environments influence business location and performance (in the knowledge and creative economy). In order to do so, this dissertation applies various quantitative methodological approaches to model individual-level business data and neighborhood characteristics. I chose to constitute this dissertation with three essays, as follows.

The first essay establishes and tests a theoretical framework that evaluates the impacts of transit and walking amenities on creative firms, the number of KIBS, and innovation productivity. These three factors-number of creative firms and KIBS, and innovation productivity-could indicate the robust knowledge economy (Shearmur 2010, 2012; Zandiatashbar and Hamidi 2018). In this essay, I also control for the effects of other factors that have been theorized to be influential on the locational behavior of knowledge and creative economy firms. Such factors include measures for tolerance, local economic condition, place quality, built environment, and distance to Central Business District (CBD). Drawing upon the literature I hypothesize that although KIBS, creative firms, and innovation productivity are all key drivers of the knowledge economy, KIBS and creative firms play the mediating role between locational and non-locational factors and innovation productivity (Boschma 2005; Cooke 2001; Furman, Porter, and Stern 2002).

After developing a theoretical framework to evaluate the impact of transit and walking amenities on firm location in the creative and knowledge economy, I investigate whether TODs play any role in enhancing the productivity of the knowledge and creative economy in the second essay. In addition to station proximity, I also control for the level of density, land use diversity, and walkability to distinguish TODs from non-TOD station areas. I also account for internal and external firm-level characteristics to explain the differences in productivity of firms. The indicator of productivity in this analysis is firm-level sales volume.

In the third essay**,** I examine the location/mobility preferences of different high-tech industries with respect to transit and walking amenities. To identify these possible different preferences, first I identify specialized high-tech zones in large U.S. regions. Secondly, I measure and identify the industrial specialization of each zone. Finally, I investigate to what extent these zones are different in terms of transit accessibility and walkability and which specialized high-tech zones are more likely to be transit-accessible and walkable.

Research Questions

This dissertation seeks to answer the following questions:

1) What is the impact of transit and walking amenities on creative firms, number of KIBS establishments, and innovation productivity?
    a) To what extend will the impact of transit and walking amenities be different between firms in the creative economy and STEM knowledge-based economy?
2) Are creative industries and knowledge-based firms that are located in TODs more productive than those in non-TODs? What is the average difference between these firms?
3) Where are the U.S. specialized high-tech zones?
    a) Do different high-tech specializations have also different preferences in terms of transit accessibility and walkability?
    b) If so, which high-tech specializations are more likely to embrace transit accessibility and walkability?

Research Significance

The three essays in this dissertation have implications for academia, the policy development arena, developers, business owners, and stakeholders. Compared to the existing literature, this study is among few studies that provide empirical analyses at the national level and evaluate the economic impact of transit and walking amenities. Furthermore, using the address-level datasets on the location of knowledge-based and creative businesses, as well as innovation productivity in the U.S., makes the results of this study unique. The limited existing quantitative analyses in the literature relied on the North American Industry Classification System (NAICS) and the Two-Digit Industry Category (Chatman et al., 2016; Credit, 2018; Nelson, Mweller, Eskic, Kim, & Ewing, 2015). This dissertation is distinguishable from the literature in terms of sample firm selection. For the sample firm selection, I used the NAICS 8-digit industry codes. This allows my analysis to be more exclusive in terms of firm selection and enables the analysis of the differences between the knowledge economy industrial subcategories, which is a major gap in the literature.

Furthermore, the second essay stands distinguishable from the literature by controlling for the built environment attributes of station areas. While previous studies only consider station proximity for their analysis (Chatman et al., 2016; Credit, 2018; Nelson et al., 2015), my identification of TODs draws upon controlling for the density, land use diversity, and walkability within the station areas. My analysis of TODs is among the first attempts in the U.S. that controls for the built environment traits of station areas to distinguish between TODs and non-TODs. It is also the first study that employs the disaggregated firm-level data at the national scale.

In the third essay, using geospatial techniques, including local Getis Ord G*, tessellation, and firm level data, I identify the specialized high-tech zones at the most disaggregated geographic area in every U.S. region. Previous attempts at identifying the economic clusters/zones did not identify high-tech clusters at less than a county level (Delgado, Porter, and Stern 2015; Fallah, Partridge, and Rickman 2013; E. Feser 2004). Additionally, my third paper accounts for different sectoral categories of high-tech industries, as they could have different accessibility needs. While most studies on the accessibility needs of high-tech firms emphasize the expansion of transit services and enhancing walkability using the agglomeration and placemaking frameworks, those firms that are impacted by the new logistic revolution, land values, easy access to the global e-economy, and rise of online workers could prefer strong highway systems (Audirac 2005; Maggioni 2002).

Dissertation Outline

The remainder of this dissertation contains four chapters. Chapter 2, 3, and 4 include the background, research questions, analytical framework, research process, and analytical method for each of the three essays. The last chapter covers the policy implications and a variety of potential negative externalities that come with the growth of the knowledge economy and provide a policy matrix based on these negative externalities.

Chapter 2_Essay 1: IMPACTS OF TRANSIT AND WALKING AMENITIES ON ROBUST LOCAL KNOWLEDGE ECONOMY[1]

Introduction

Knowledge Intensive Business Services (KIBS) contribution to the U.S. Gross Domestic Product (GDP) is above-average productivity. As of 2013, KIBS employed almost 10% of the U.S. employment and generated nearly 20% of national GDP which will increase to nearly 25% during the next two decades (Muro and Liu 2017). KIBS share in European Union (EU) labor force has also increased and Research and Development (R&D) alone held over 1.2% of 2015 EU labor force (Europe 2020 indicators - R&D and innovation - Statistics Explained 2010) . Eurostat 2020 goal is to increase investment in KIBS to 3% of their GDP in order to bypass their competitors, Japan and the U.S. (Uppenberg 2010). KIBS and creative enterprises also facilitate innovative activities in other sectors through which they let their significance go far beyond themselves (Bakhshi, McVittie, and Simmie 2008; Cooke and Leydesdorff 2006).

A considerable amount of literature on the determinants of robust local (neighborhood-level) knowledge economy point out to non-locational factors including racial diversity, sexual diversity and share of bohemian residents which establish the social trust for further face-to-face contacts and attract creative class (Bereitschaft and Cammack 2015; Florida 2002a; Knudsen et al. 2008; Rao and Dai 2017). Share of educated population also is an indicator of access to skilled labor force which attracts KIBS and boosts the innovation productivity (Joseph, Mullen, and Spake 2012; Müller, Rammer, and Trüby 2009; Shearmur 2012) and so do the university and

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private R&D expenditures (Acs, Anselin, and Varga 2002; Black 2005; Crescenzi, Rodriguez-Pose, and Storper 2007; Furman, Porter, and Stern 2002).

In addition, previous studies shed light on several locational determinants of innovation such as spatial clustering which attracts KIBS through agglomeration externalities (Audretsch and Feldman 2004; Wallsten 2001), proximity to Central Business Districts (CBDs) (Shearmur, 2010) and place quality amenities which attract creative class, talents and KIBS, and thus, boost innovation productivity (Florida, 2014; Shearmur, 2010). Furthermore, density and land-use diversity found to enhance the face-to-face contacts and embed an urban buzz which leads to increase of innovation productivity (Storper and Venables 2004; Wood and Dovey 2015).

In addition to these factors and according to the theoretical frameworks such as agglomeration theory and the theory of amenity richness, transportation infrastructure (more specifically walking and public transit) could contribute to a robust local knowledge economy. Theory of amenity richness emphasizes on the role of transit and walking amenities as the place quality preferences of the skillful millennials responding to their car-free life style, strong desire for urban social life and living in mixed-use and compact urban areas (Shearmur, 2012). The agglomeration theory discusses the role of transportation infrastructure in expanding access to the suppliers as well as widening firms' customer and labor market areas (Van der Panne 2004).

The key question with regard to these theories is whether the mechanism to which transportation infrastructure could affect innovation is similar for creative industries versus knowledge industries? How does it compare to other locational and non-locations drivers of innovation? While several studies have stated these relationships theoretically (Boschma, 2005; Cooke, 2001; Furman et al., 2002), there is little empirical evidence into such mechanism of impacts.

To fill this gap in the literature, this research seeks to find whether and to what extent transit and walking amenities impact knowledge industries, creative enterprises and innovation productivity. By using Structural Equation Modeling (SEM), this study controls for both direct and indirect impacts of transit and walking amenities on these three drivers of the knowledge-based economic vitality. This study hypothesizes two mediating (intermediate) variables, KIBS and creative firms, between transit, walking and innovation productivity and report direct, indirect and total effects.

Using ESRI Business Data Source (EBDS) and Small Business Innovation Database (SBIDB), this study is one of the first attempts at the national level to combine disaggregated address-level datasets on the location of knowledge-based and creative firms in tandem with innovations in the U.S. Moreover, my empirical analysis controls for other locational and non-locational factors that are theorized in the literature to be the key determinants of robust knowledge economy at the neighborhood level. This analysis draws upon an international literature in order to echo or provide updates for the previous theoretical predictions. Several locational and non-location drivers of innovation, supported by these theories, are observed to be significant in the US, Australia, Beijing, Austria, Norway as well as other counties (Knudsen et al. 2008; Müller, Rammer, and Trüby 2009; Rao and Dai 2017; Wood and Dovey 2015). Observation of such mutual findings in different countries would suggest that since there is little understanding on the impacts of transit and walking amenities on the three aforementioned drivers of robust knowledge economy internationally, the U.S. experience might be generalizable.

Literature review

Creative industries, KIBS, and innovation productivity

This research focuses on the impacts of transportation infrastructure on the three factors of knowledge-based economic vitality including creative industries, KIBS and innovation productivity while controlling for the inter-relationships between them. This section reviews the existing literature about the definition of KIBS, creative industries and innovation productivity as well as their interactions.

Creative industries

Since the creative industries contribute to the today's economic growth, the main question revolves around those belonging to this category. To ansIr this, scholars have addressed the nature of occupations.

Florida (2002a) classifies the creative occupations in two ways: the “super-creative core” and the “creative professionals”. The “super-creative core” directly generates new products and ideas while “creative professionals” apply knowledge to solve problems. Florida's “super-creative core” includes the industry categories defined by the U.S. government and “creative professionals” are working in management operations and consultations (Florida, 2002a). Situating Florida's creative occupations as the common agenda has been debatable in the literature. For instance, Rausch and Negrey (2006) raise two major points regarding Florida's creative industries. First, this determination is not inclusive enough, and second, this classification is not homogenous enough to independently dominate the economic performance (Rausch & Negrey, 2006).

Addressing these shortcomings, Markusen et al. (2008) introduced the cultural occupations representing the creative industries. Cultural industries are those establishments—for profit, nonprofit, and public—that develop cultural goods and social services. The cultural occupation classification excludes Science, Technology, Engineering, and Mathematics (STEM). Markusen et al. (2008) prioritize these rubrics for their sector selection over the U.S. governmental definition used by Florida (2002a). The U.S. governmental definition is largely based on educational attainment and credentials resulting in the exclusion of all creative workers without degrees (Markusen et al. 2008).

KIBS

The other category of businesses that contributes to the local and regional knowledge-based economic vitality is KIBS. KIBS have been attracting the attention of academics and policy makers due to their fast and consistent growth since 1970 (Shearmur, 2012). KIBS are characterized by their deep investment and reliance on technology R&D and STEM workers. KIBS are classified into two groups including the technology-based services (T-KIBS) (IT related services, engineering, and R&D consulting firms) and the management-related or professional services (M-KIBS/P-KIBS) (business consultancy, advertising, marketing, and media).

A national assessment of advanced industries prepared by Brookings Institution introduces KIBS sectors, which correspond to the determinations in the U.S and non-U.S. prominent studies (Shearmur, 2010). Brookings' criteria for identifying the U.S. KIBS are geared mostly toward STEM and high-tech R&D activities. The present study adopted Brookings' criteria in my study, which are as follows:

1) The R&D expenditure per worker must be in the 80th percentile of industries or higher and exceed $450 per worker.
2) KIBS occupations require a high degree of STEM knowledge, which should be above the national average, or 21% of all workers.

Applying these criteria, Brookings identified 50 industries in developing, diffusing, and applying new productivity-enhancing technologies as KIBS occupations (Muro and Liu 2017).

Having defined creative industries and KIBS, the major question is how they contribute to the innovation productivity. According to an empirical study from the UK, industries that trade more with creative occupations perform stronger on various innovation measures (Bakhshi et al., 2008) while it depends on the type of creative occupation. For instance, Austrian ICT industries show significantly more support for innovation compared to other creative sectors (Müller et al., 2009). However, these analyses have not addressed the locational impacts of creative industries on innovation outcome. Second, the Austrian and several other empirical studies rely on the number of innovation that creative industries reported in the surveys. Studies show that, the innovation surveys have the potential of overestimation and to overcome this issue relying on the number of patents or innovation counts collected by the independent entities could be more reliable (Acs, Anselin, and Varga 2002).

Similarly, KIBS contribute to science-based and technology-driven innovation. They are also the knowledge intermediaries for other innovative sectors and businesses (Gallouj 2002). Hertog (2000) points to KIBS as the “Second Knowledge Infrastructure” after “First Knowledge Infrastructure” such as universities (Hertog, 2000). Cooke and Leydesdorff (2006) also conclude that KIBS play an important role in the innovation system via facilitating knowledge transmission (Cooke and Leydesdorff 2006). To investigate these theoretical assumptions, there is a need for further empirical analysis into such impacts.

Locational and non-locational determinants of creative industries, KIBS and innovation productivity

According to the Iberian industrial location theory, firms tend to locate where they can minimize their production costs including transport costs of input and output and the local costs of acquiring labor (Weber, 1929). This theory could be applicable in knowledge economy with the understanding that excluding the quality of material to be transported and the quality of labor to be acquired is the main shortcoming of Iberian theory (Fetter 1930). KIBS and creative industries are characterized to be footloose since they require minimum working capital. Also, locating in proximity to customers is not a big factor in transport costs of their output. This is because they mostly generate immaterial services which could be transferred via online networks. However, their major input is information or knowledge and consequently easy access to information strongly determines their location (Shearmur, 2010).

One key principle in the location determination of knowledge-based firms is spatial clustering. Spatial clustering leads to specialization externalities of agglomeration by catalyzing spillover effects such as frequent knowledge exchange between similar industries, lower access cost to the larger labor pool and suppliers and ultimately product's value chain (Van der Panne, 2004). Innovation productivity and KIBS location behavior are widely analyzed with respect to the spatial clustering (Feldman & Florida, 1994; Shearmur, 2010; Wallsten, 2001). For instance, (Wallsten 2001) analyzed the clustering theory for the U.S. innovative firms and found that if innovative firms cluster within a 0.25 mile proximity, their innovation productivity will be increased.

Building on this hypothesis, Boschma (2005) stated that the spatial proximity leading to knowledge spwell over could be more effective when coupled with the cognitive proximity. Cognitive proximity refers to the required knowledge similarity for intra- and inter-firm knowledge transfers. Cognitive proximity highly depends on an individual's level of knowledge or in the other words, knowledgeable workforce (Boschma, 2005). Consequently, innovation supportive businesses (particularly KIBS) are characterized by their investment and reliance on technology R&D and STEM workers. Aligned with Iberian location theory, access to the larger pool of knowledgeable workers (minimized local costs of acquiring labor) is a fundamental location criterion for KIBS and creative industries (Shearmur, 2012). A recent study of Canadian KIBS, for instance, found that T-KIBS location decisions highly depend on the local presence of university graduates (Shearmur, 2010). Despite the popularity of specialized clustering in U.S., Italy, Portugal, France, Japan, China and its contribution to industrial district concept, Grabher (1993) points out to its possible negative impacts as clustering can result in lock-in effects as the result of a too much concentration of one specialty. Such critics call for more attention to the benefits of collocation of diverse industries in different aspects such as firm size diversity and income or STEM-cultural industry diversity.

The significant role of human capital in new urban economics led to the rise of amenity richness theory (Florida 2002a; Trip 2007). Amenity richness theory principle pillar is the local place-based characteristics that satisfy quality of life of skillful millennials such as their car-free life style, strong desire for urban social life and live in mixed-use and compact neighborhoods (Shearmur, 2012). As the result, this theory implies that the creative and educated classes highly prefer to live within walkable distances to restaurants, retail, and cultural and educational institutions. Several European, American and Asian empirical studies also confirmed the emergence of creative class clusters in areas with such local amenities (Florida 2002a; Pacione 1990; Rao and Dai 2017; Trip 2007). (Trip 2007) in Amsterdam and (Rao and Dai 2017) in Shanghai tested this theory and found that the presence of a creative class significantly correlates with the number of cafes, gyms, convenience stores and green spaces.

American and European studies also report an increasing preference for living in dense and compact neighborhoods, emphasizing the importance of population and activity density on innovation productivity (Credit, 2017). According to Jacobs (1969) and Storper and Venables (2004), creativity in a neighborhood could be the result of an increase in density of population and activities . The reason is that, population and activity densities facilitate the formation of an urban buzz which hosts the frequent face-to-face contacts leading to higher chances of knowledge spillover, and in turn, higher knowledge-based economic productivity (Storper & Venables, 2004). Concerning productivity, previous studies show doubling the density increases metropolitan area productivity by 2–4% in the U.S. and 2–3.5% in France (Combes, Duranton, & Gobwellon, 2010). Proximity to Metropolitan urban cores-Central Business Districts (CBDs) - is another determinant of KIBS location decision-making through Christaller's central place theory. In view of this theory, KIBS fall in the high-order service category, which unlike the low and medium order service that locate frequently and homogenously, need to concentrate in central cities in order to cover a wider market area (Shearmur, 2010). Recent evidence from Canada also confirms that KIBS are more likely to locate in the largest cities, excluding T-KIBS that prefer the peripheral cities (the immediate suburbs to the CBDs) (Shearmur, 2010).

Social tolerance, social capital and trust Ire also found to be the key drivers of creative industries and KIBS location decisions (Boschma, 2005). According to Florida (2002a), tolerance (and socioeconomic diversity) are key ingredients in creative class theory that denote the significance of openness, racial diversity, and social inclusion. Although the contribution of tolerance to creative class size is widely accepted in theory, the existing empirical literature provides mixed evidence. While in some cases a positive relationship between sexual and racial diversity and the presence of a creative class is observed, several studies reported adverse or non-significant direct relationships between sexual diversity and innovation productivity (Bereitschaft and Cammack 2015; Knudsen et al. 2008; Rausch and Negrey 2006). This suggests that, what directly attracts KIBS and the creative industries, might not have similar impacts on innovation productivity.

Finally, walkability and transit quality could contribute to the knowledge-based economic vitality. Walkability is recognized as an important local amenity for college-educated millennials when they choose a place to live and work after graduation (Leinberger and Lynch 2015). An Austrian study, for instance, found that members of the creative class tend to cluster in walkable adjacency surrounded by a diversity of activities (Wood & Dovey, 2015). Walkability is the lifestyle of millennials and university graduates as they are relatively more car-free (K. Credit, 2017; TransitCenter, 2016; Urban Land Institute, 2015; Iissmann, 2012). Millennials own 12% fewer cars than previous generations and are less likely to be licensed drivers. The car-free lifestyle is also supported by living in denser places, which have on average twice the level of transit access to jobs as do older generations (Klein and Smart 2017).

Transit quality is another local amenity that attracts the creative class. Recent empirical studies confirm that U.S. innovative firms tend to locate in walkable neighborhoods with more frequent transit trips (Hamidi & Zandiatashbar, 2018; Hamidi and Zandiatashbar, 2017a, Hamidi and Zandiatashbar, 2017b). Public transit infrastructure reduces travel time and enhances the urbanization externalities of agglomeration by expanding the coverage area of a business. Furthermore, transit riders have more opportunities for face-to-face encounters leading to knowledge exchange (Chatman & Noland, 2011). Moreover, according to the Christaller's Central Place Theory, KIBS - at least the high-order components of KIBS - tend to be concentrated toward the top of the urban hierarchy, in the largest and most accessible cities. Therefore, their location decisions could depend on proximity to major transportation hubs such as major regional airports, railway or transit stations. This helps KIBS to be more accessible for a wider range of customers while obtaining a larger pool of skilled workers (Shearmur, 2010). While the transit network improves accessibility to a larger labor and marker areas, transit stations as the urban nodes also increase the visibility of surrounding businesses (Credit, 2017). These impacts are confirmed by recent empirical studies that found transit station proximity leads to an 88% increase in Phoenix knowledge startups with similar observations in Dallas and Portland (Credit, 2017; Noland, Chatman, & Klein, 2014). While interpreting the results of such empirical analysis as the proof for the aforementioned theoretical relationships, shortcomings in these analyses should be also considered. The majority of such empirical studies employ the Longitudinal Employer-Household Dynamics (LEHD) data and researchers to identify the knowledge start-ups used the 2-digit North American Industry Classification System (NAICS) sector number, which does not necessarily provide enough detail to control for the STEM and R&D nature of these firms. Moreover, such studies have yet to include indicators of innovation outcome and creative industries. Therefore, the key question that whether the mechanism to which transportation infrastructure could affect innovation is similar for creative industries versus knowledge industries is still unanswered. Figure 2-1 ilustrates the theoretical framework linking transit, walkability, and the local knowledge economy.

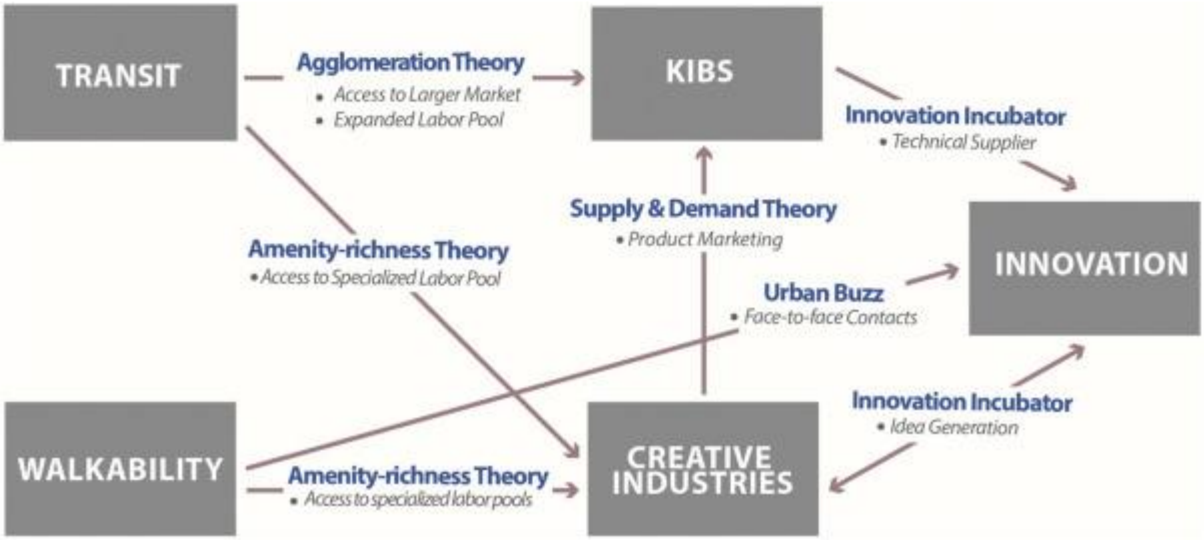

Figure 1: Theoretical framework demonstrating the links between transit, walkability, and the knowledge economy at the neighborhood level.

While amenity richness theory is one of the widely accepted frameworks to explain the impacts of place-based qualities such as walkability and transit accessibility on KIBS, creative industries and innovation outcome, several researchers have challenged this theory. For instance, several empirical studies found that such amenities might lead to increasing property value, which could act as a disamenity for the tech firms particularly the smaller tech firms with limited financial resources (Pivo and Fisher 2011). Moreover, a different line of research argues that in spite of the growth and concentration of KIBS and creative industries in Well urbanized areas, their innovation output are determined first and foremost by firm-specific characteristics and strategies that are independent of their location (Doloreux, Amara, and Landry 2008; Doloreux and Shearmur 2012; Shearmur 2012).

This study aims to provide empirical evidence on the role of walkability, transit and place quality urban amenities on attracting the creative industries, knowledge-based firms, supported by the theory of amenity richness, Christaller's central place theory and agglomeration economy. This study also seeks to investigate the intermediating role of creative and knowledge-based firms in innovation productivity of other firms.

Table 1 summarizes the existing international studies on several locational and non-locational factors such as industry clustering, population and activity density, quality of place amenities, distance to CBDs and social tolerance as the essential elements for knowledge-based economies. A closer look at Table 1 also implies several gaps in the literature. First, there is a general lack of research that integrates KIBS, the creative economy and innovation production discmyse and analysis regarding the impact of the above-mentioned factors. Not using a comprehensive model of these three factors has resulted in ambiguous findings. Secondly, there is a general lack of disaggregated empirical analysis addressing the role of local transit and walkable amenities in knowledge-based economies. Though several theoretical studies have stated the possibility of such a role, empirical analyses are needed to either echo or provide further inquiry to these theories. As the result of using a structural statistical analysis, the present study seeks to dismantle the complex relationships by investigating the direct, indirect and total effects for each factor.

Author(s) (Year)		Attribute	Major Finding	Impact on:	Study Country	T	QL	QN
Knudsen et. al. (2008)	CLUSTERING	*Creative Class Density*	**Creative class density (=pop. density*creative class)** facilitates innovation (# of utility patents/100,000 pop.). More f-2-f contacts in denser creative class leads knowledge spillover & more innovations.	Innovation	U.S.			●
Black (2004)		*Pop Density, SBA Firm Cluster*	**Proximity to R&D activities, knowledge sources, similar firms** and technological infrastructures and size of a geographic area have positive effects on winning the SBIR award (a measure of innovation productivity).	Innovation	U.S.	●		●
Wallsten (2000)		*Clustering of SBA firms*	Evidence in U.S. shows SBIR firms **collocating within a 0.25 mile buffer** are more likely to repeat wining SBIR in the next years.	Innovation	U.S.			●
Furmana et. al. (2002)		*Clustering of Interconnected Firms*	**Industrial clustering** can indicate the **national innovative capacity** through supportive environment for quality interaction between supply and local demand, innovation flow, local firm rivalry and access to possible local clients for innovation.	Innovation	Global	●		●
Boschma (2005)		*Geographical & non-Geographical Proximities*	Knowledge similarity for knowledge transfer, rules for networking, trust-based interaction are the requirements for **geographical proximity** to draw upon spatial clustering between agents & enhance interactive learning. The formers are **cognitive, institutional** and **social proximities.**	Innovation	-	●		
Shearmur (2010)		*Clustering, Access to Info. & Amenities*	KIBS require **access to knowledgeable workforce** and **industrial clustering**. Knowledgeable workforce require place quality **amenities**. P-KIBS locate in amenity rich areas close to **MSA core with local income growth** while T-KIBS locate in immediate suburb.	KIBS	Canada	●		●
Jacobs (1961)	PLACE QUALITY	*Mixed-Use, Walkability Density*	Creative clusters have vibrant **urban street life**, where frequent and random **face-to-face contact** happen between creative people. These clusters embrace **street connectivity, density** and a bundle of amenities in a **walkable** adjacency.	Creative Class	U.S.	●		
Trip (2007)		*Place Quality*	Amsterdam is stronger than Rotterdam in place quality with respect to **cultural industries, gay and bohemian scenes, nightlife,** and **culture and city image.** Not only are these some of the most disputed and intangible aspects of quality of place; which are strongly emphasized by Florida.	Creative Class	The Netherlands	●		●
Katz & Wagner (2014)		*Density, Mixed-Land Use, Walkability, Transit*	Innovation districts are **compact, mixed use, walkable,** and **transit accessible** and accommodating leading-edge educational institutions and talented human capital.	Innovation	U.S.	●		
Chatman (2016)		*Transit Station Proximity*	Firm birth and station proximity have positive, large and statistically significant relationships in all size and sector categories. In case of Dallas this relationship is generally positive, though not as large.	KIBS	U.S.			●
Credit (2017)		Transit Station Proximity	Station proximity in Phoenix is worth 88% increase in **KIBS startups** which is far ahead of service and retail sectors by respectively 40% and 28% increase when compared with automobile-accessible control areas.	KIBS	U.S.			●
Chatman & Noland (2011)		*Public Transport Amenities*	Public transport can foster **agglomeration** via sharing (input, output, labor and consumer market) matching (jobs and skills, less employee turnover) and learning (**knowledge spillover, face2face contact, quick dissemination of innovation**)	Innovation	U.S.	●		
Wood & Dovey (2015)		*Land use, Formal & Socioeconomic Diversity*	Creative clusters have **Socio-economic diversity, Functional** (**land-use**) **diversity** and **morphological/formal diversity (mix of lot-sizes, building age & interfaces)**	Creative Class	Australia		●	
Knudsen et. al. (2008)	TOLERNCE	*Gay & Boehmian Indexes*	Their empirical evidences from U.S. MSAs shows that **gay** and **bohemian indices** (location quotients) **are not** the directly driving MSA **innovation** capacity, whereas drive the creative class (including talents and industries).	Innovation	U.S.			●
Florida (2002)		*Racial Diversity, Gays, Bohemians*	Tolerance and technology attract creative class. Acceptance of newcomers, gays and bohemians in this framework indicates the level of tolerance. Accordingly, density encourages face to face contact leading to higher social capital as the prime need for tolerance.	Creative Class	-	●		
Roa & Dai (2017)		*Gay Index, Place Qualities*	**Gay index, racial diversity** and **place qualities** contribute to increase of creative class size in Shanghai, China.	Creative Class	China			●
Bereitschaft & Cammack (2013)		*Income and Sexual Diversity*	A significant positive relationship between the creative class and percentage of gay households and income diversity, but not racial or linguistic diversity in Chicago. Overall, **diversity does not strongly predict the creative workers location.**	Creative Class	U.S.			●
Florida (2002)	OTHER SUPPORTS	Technology & Talent	As was mentioned, **technology** attracts creative class (talents) who are the drivers of creative clusters.	Creative Class	-	●		
Furmana et. al. (2002)		*Technology, Knowledge Workers, R&D Intensity, Policy Support*	Drawing upon endogenous growth theory (equal to **knowledge stock & R&D labor pool**), **industrial clustering** and national innovation system (supportive and protective policies), national innovation capacity comprises 1st presence and condition of **innovation infrastructures**, 2nd presence and quality of **industrial clustering** and 3rd the **linkage between these two.**	Innovation	Global	●		●

Table 1: Summary of existing literature on locational and non-locational determinants of knowledge economic vitality

Methods

To my knowledge, this research is among the first attempts at the national level in the U.S that empirically analyze the impact of transit and walking amenities on knowledge-based economic vitality at the block group level while controlling for both direct and indirect impacts. In order to do so, this research conducted a multidimensional analysis of all three actors of the knowledge economy (KIBS, creative industries and innovation production) at the neighborhood level.

Data and variables

The literature on the determinants of innovation output and knowledge economy is vast and the list of influential factors varies depending on the definition of knowledge economy and the level of analysis. The majority of previous studies have focused on the regional and state level determinants of knowledge economy and pointed out to factors such as the university R&D expenditure, private R&D input as well as state's share of high-tech firms in GDP and state and regional policies and regulations (Acs, Anselin, and Varga 2002; Aghion et al. 2015). A different line of research discusses the role of firm-specific characteristics and strategies on innovation that are independent of the firm locations. Firms' characteristics include managerial quality, firm's R&D expenditure, intellectual property rights strategies and policies, available financial capital such as firm's worth value and revenue as well as annual hours of training for employees, and number of knowledge workforce in high-tech sectors (Doloreux, Amara, and Landry 2008; Doloreux and Shearmur 2012; Shearmur 2012).

This study focuses on the local (neighborhood-level) determinants of innovation. My list of variables (see Table 2) corresponds to the list of factors found from previous neighborhood-level studies presented in table 1. My sample includes 3088 U.S census block groups with at least one innovation award between 2013 and 2015. This study initially used innovation data for a single year, 2015, but found that due to the rarity of SBIR innovation awards, <1% of block groups contained any innovation award. There was also little variance in the dataset for one year innovation awards, again due to the random element of innovation awards. When this study instead used a three-year average, it reduced the number of census block groups with zero innovation award and hence increased my variance and sample size. The correlation between the innovation awards in one year (2015) and three-year (2013–2015) periods is 0.904, with 99% confidence level of significance, which indicates the two periods are highly correlated.

Category	Variable	Variable Description	Data Smyce
Endogenous Variables			
INNOVATION	Innovation	Natural Logarithm of number of innovation awards in the block group	Small Business Innovation Database 2000 - 2015
CREATIVE CLASS	Creative Class*	Number of people in the block group employed in the creative industries based on the Markusan et. al (2008) definition of creative industries	ESRI Business Data Smyce (2015)
KIBS	KIBS**	Number of firms in the block group that meet the Brookings' KIBS criteria	ESRI Business Data Smyce (2015)
Exogenous Variables			
CLUSTERING	Activity Density	Activity density (sum of population and employment divided by gross land area in square miles)	Computed using the LEHD and census data 2010
	Location Quotient	Location quotient for the qualified businesses for the SBIR grant program	Computed using the ESRI Business Data Smyce (2015)
PLACE QUALITY	Transit	Average transit service frequency in every individual block groups	Smart Location Database-EPA (2010)
	Walk	Predicted number of walk trip in every individual block groups	Computed using the NHTS, Census, LED and street network data
	Amenity	Number of amenities indicating the place quality in every individual block groups	ESRI Business Data Smyce (2015)
TOLERANCE	Racial Diversity	Melting Pot index, percentage of foreign-born people in every individual block groups	Census ACS (2015) (5 year estimate)
	Bohemian	Number of employees belonging to the bohemian services based on the Florida (2002) study	ESRI Business Data Smyce 2015
OTHER SUPPORTS	Job Growth	Employment change between 2011 and 2014	LEHD
	Distance to CBD	Distance from the census block group's population centroid to the closest Central Business District(CBD)	Hamidi et al. (2015)

* For more information on the descriptions and NAICS codes of creative businesses see Markusen et al., 2008, pp. 40-42.
** For more information on the descriptions of KIBS see Mark et al., 2015, p. 3.

Table 2: Descriptions and source of model variables

Table 2 provides details for the variables and data sources. For my measure of innovation counts, this analysis used the Small Business Innovation Research (SBIR) and the Small Business Technology Transfer (STTR) data provided by the US federal agency, Small Business Administration (SBA). SBIR/STTR is a U.S. governmental program supporting STEM-based innovations with commercial value at the small firms. The SBIR qualified firms have <500 employees and are usually among computer science, process control instrument, radio and TV communication, semiconductor, bio-tech and manufacturing instrument for electricity services. Such firms enter a 3-phase competition for SBIR and STTR awards to support their product innovation (Audretsch and Feldman 2004; Wallsten 2001). Phase I assesses the feasibility of idea, proof of innovation concept from small business, phase II provides support for the research and development for a prototype among phase I grantees, and phase III is the commercialization phase among selected phase II grantees. My innovation count is the number of SBIR and STTR phase I and II grants due to data availability. SBA does not release data on the phase III awardees.

SBA is the best and only available disaggregated innovation data at the national level. The availability of this data at the address-level has made it more applicable for the local level empirical analysis. The SBA data is a widely used as the measure of innovation counts in the US (Acs et al., 2002). Compared to other measures of innovation counts, the SBA data is inclusive by not favoring large companies. Also compared to the patent data, the chance of overestimation of innovation is less as it aims to award only innovations with the commercial value (Hamidi and Zandiatashbar 2017; Zandiatashbar et al. 2019; Zandiatashbar and Hamidi 2018)

This study posits two mediating variables connecting transit and walking with innovation indirectly: creative industries and KIBS. My first mediating (endogenous) variable is the number of creative industries borrowing the classifications in Markusan et al. (2008). Markusan team included only art-based and cultural economies in their creative class definition. I obtained the North American Industry Classification System (NAICS) sectors for the creative industries in the categories of religion, sports, recreation and entertainment, education, information, supplier sectors and distribution only if they involve in cultural activities and not STEM. Using the address-level firm location data from EBDS 2015, I aggregated up the number of these businesses to the block group level.

My second mediating (endogenous) variable is KIBS. As explained earlier, I used the NAICS codes provided in Brookings' "America's Advanced Industries" report to identify KIBS firms. I obtained this variable through the address-level firm location data from EBDS 2015 and then aggregated up to the block group level as my unit of analysis.

The numbers of KIBS and creative industries serve as meditating variables between the number of innovations and my exogenous variables of tolerance, local economic condition, place quality, built environment and transit quality

Industry clustering: I developed location quotients using Eq. (1) to represent the spatial clustering of the innovative firms in every individual census block groups. Location quotient has been widely used as a measure of clustering particularly in geography of innovation studies (Feldman & Florida, 1994). Using EBDS 2015 data set I calculated the location quotient of SBIR qualified firms with respect to the employment size and sectors. These location quotient sectors corresponds to the sectors included in my endogenous innovation variable.

$$\left(\left(\frac{Block\ Group\ SBA\ Qualified\ Emp}{Block\ Group\ Emp}\right)\Big/\left(\frac{MSA\ SBA\ Qualified\ Emp}{MSA\ Total\ Emp}\right)\right) * 100 \tag{1}$$

Place Quality Amenities: regarding the important role of place quality amenities in robust knowledge economy, I included the number of *restaurants, café's, discos, nightclubs, theatres/concert halls, museums, cinemas, sports facilities, recreation areas, and public libraries* and *parks* in each block group using EBDS 2015. These amenities have been widely used in other empirical studies assessing the theory of amenity richness in North America, Europe, Asia and Australia (Florida 2002b; Rao and Dai 2017).

Distance to CBD: I obtained the CBD locations from Hamidi (2015) and computed the network distance from a block group population centroid to the closest CBD. Hamidi (2015) used the spatial statistics and geographically weighted regression techniques and identified the location of central business districts (CBDs) and employment sub-centers for all metropolitan areas in the U.S.

Walking: The two exogenous variables of greatest interest are walkability and transit amenities. My walkability variable is the predicted walk trip per household. Several studies including Cervero and Radisch (1996) used the number of walk trips in a neighborhood as an indicator of walkability (Cervero and Radisch 1996). I modeled the predicted walk trips for every census block groups using the data per household's characteristics and travel behavior. These data Ire retrieved from National Household Travel Survey (NHTS) and American Community Survey (ACS) (2007-2010). The household characteristics data includes household size, household income, and number of household workers. I used NHTS to count the total walking trip per household members in order to validate my model. Merging the household data with built environmental attributes of each block group; using the national street network data in ArcGIS, allowed us to predict the walk trips for each census block group through equation 2:

$$\alpha = e^{x}\begin{pmatrix} -1.57 + 0.231 \times b + 0.036 \times c + 0.00327 \times d + 0.00281 \times f + \\ 0.00281 \times g + 0.172 \times h + 0.00254 \times j + 0.00644 \times k \end{pmatrix} \tag{2}$$

The equation 2 was developed by a negative binomial regression; a statistical method that applies to count data, where *a* is the predicted walk trips, *b* is the average household size, *c* is the average household workers, *d* is the average household income in 1000s, *f* is the activity density per 1000s, *g* is the entropy, *h* is the intersection density and *k* is the percentage of four-way intersections. Ultimately, I validated my model vis-à-vis NHTS data on total walk trips.

Transit Quality: My transit quality variable indicates the transit frequency per square mile of land area obtained from Smart Location Database (SLD) developed by Environmental Protection Agency (EPA). SLD contains the data of transit frequency for each route between 4:00pm and 7:00pm on Iekdays and for each census block group they used the services that stop every quarter of miles. Then dividing this data by the block group land acreage results in the transit frequency per square mile (Ramsey & Bell, 2014, p. 24). This measure is widely used in other studies to investigate the impacts of transit amenities on economic outcomes, housing affordability and innovation productivity (Appleyard et al., 2016; Hamidi & Zandiatashbar, 2017a).

Tolerance: I controlled for tolerance using the variables that have been broadly examined in the literature of creative economy with a big difference that this study is conducted at the block group level while other U.S. studies conducted at the regional level (Rausch & Negrey, 2006). ACS five year estimate was used to calculate the percentage of foreign born residents at each census block group representing the local level of open-mindedness (Hoyman and Faricy 2009). My other indictor of tolerance is the number of bohemians. According to Florida (2002), bohemian is the artistically creative class consists of authors, designers, musicians, composers, actors, directors, painters, sculptors, artist print makers, photographers, dancers and performers (Florida 2002b). My EBDS 2015 also includes the number of employee at each industry, which allowed us to calculate the percentage of the employees that work at the bohemian services. Another advantage of EBDS 2015 is availability of the eight-digit NAICS sector thus helps identifying these sectors at the finer level.

Statistical analysis

I used the SEM to assess the effect of transit quality and walkability on robust knowledge economy at the block group level. This "model-centered" methodology seeks to assess theoretically justified models against data (Grace, 2006). SEM stimulates the estimations via solving a set of equations. This set of equations are divided to ones for endogenous variables in the network and the variables that solely influence other variables, which are called exogenous.

My SEM model of innovation production function was estimated using IBM SPSS Amos 22 and maximum likelihood procedures. My model initially was based on my multidimensional theoretical framework and I added changes and improvements via computing the modification indices. These indices recommend a set of improvements corresponding with the model and datasets. However, I only considered the recommendations that Ire aligned with my theoretical justifications. The modification indices help researchers identify the possible missing links only if the input is a dataset with no missing information.

I also used the simple bivariate relationships and data for frequency distribution to identify the needs for data transformation. Therefore, I log transformed my dependent variable which was the number of innovations. This transformation helps with eliminating the issue of outliers and allows interpretation of results from the regression coefficients in elasticity. Therefore, one unit of change in the independent variables correspond with percentage changes in the dependent variable. I report the following measures of my analysis fit: chi square, the root mean square error of approximation (RMSEA), and the Comparative Fit Index (CFI). My results are also reported as standardized regression coefficients.

Results

Fig 2 represents the best fitted model. Causal pathways are illustrated via straight uni-directional arrows and dashed bi-directional arrows represent correlations with the standardized regression coefficients above the lines. To simplify the already complex causal diagram, some correlations are omitted from the diagram but not from the model as presented in Table 3. The endogenous variables are in black solid boxes. The current model has a chi-square of 6.796, which is relatively low with 7 degrees of freedom and a P-value of 0.450 which is considered high (>0.05). All these measures indicate a good model fit. In addition, the CFI value indicates that the model explains 99% of the total discrepancy in the data.

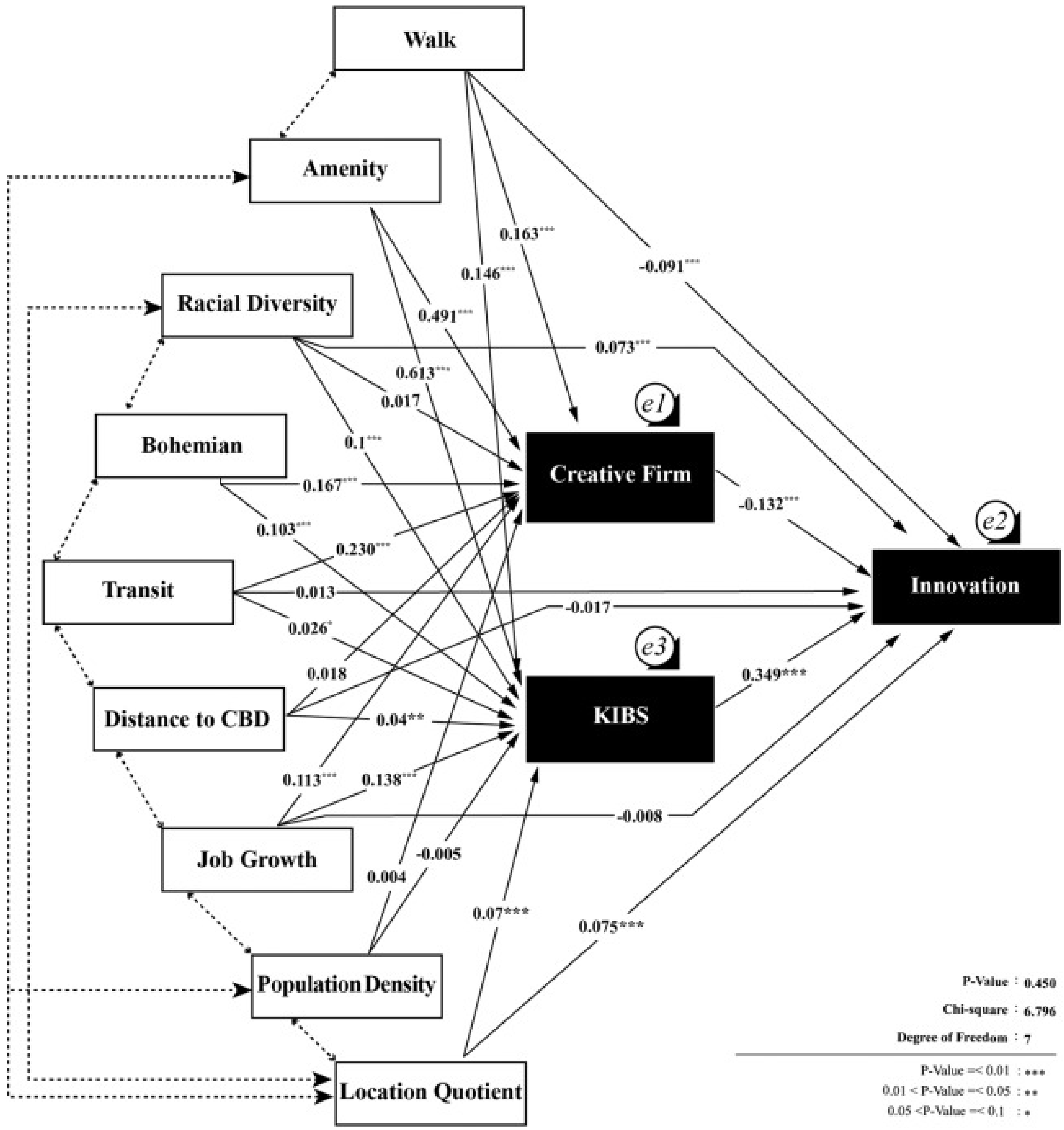

Figure 2: Causal path diagram for block group level walkability, transit quality and innovation production.

	Standardized Coefficient	Std. Error	Critical Ratio	P-value
Creative Class <--- Walk	0.037	38.61	1.36	0.174
Creative Class <--- Amenity	0.166	3.97	10.91	<0.001
Creative Class <--- Racial Diversity	0.017	1.19	1.31	0.192
Creative Class <--- Bohemian	0.093	0.42	6.65	<0.001
Creative Class <--- Transit	0.078	0.10	4.94	<0.001
Creative Class <--- Job Growth	0.033	0.01	2.49	0.013
Creative Class <--- Activity Density	0.104	0.48	3.57	<0.001
KIBS <--- Location Quotient	0.101	0.09	11.22	<0.001
KIBS <--- Job Growth	0.139	0.00	15.41	<0.001
KIBS <--- Distance to CBD	0.032	0.04	3.48	<0.001
KIBS <--- Creative Class	0.066	0.00	6.89	<0.001
KIBS <--- Transit	0.054	0.00	4.96	<0.001
KIBS <--- Activity Density	0.152	0.01	14.33	<0.001
KIBS <--- Amenity	0.574	0.09	54.67	<0.001
KIBS <--- Racial Diversity	0.089	0.03	9.72	<0.001
KIBS <--- Bohemian	0.078	0.01	8.16	<0.001
Innovation <--- Creative Class	-0.031	0.00	-2.23	0.026
Innovation <--- KIBS	0.350	0.00	22.62	<0.001
Innovation <--- Location Quotient	0.121	0.00	9.20	<0.001
Innovation <--- Racial Diversity	0.103	0.00	7.73	<0.001
Innovation <--- Distance to CBD	-0.071	0.00	-5.26	<0.001
Innovation <--- Walk	-0.117	0.02	-7.93	<0.001
Innovation <--- Transit	-0.048	0.00	-3.14	0.0016
Innovation <--- Job Growth	-0.027	0.00	-2.05	0.04
Chi-square:	3.451 Degrees of freedom = 6 P-value = 0.751			
RMSEA:	0.0 P-value= 0.998			
CFI:	1.0			

Table 3: Standardized Direct Effects of Variable on One Another in the Innovation Production Model

The standardized regression coefficients for exogenous and endogenous variables are provided in Table 3. Table 4 also shows the direct, indirect and total effects. The majority of direct relationships are highly significant with the expected sign. Among all exogenous variables, racial diversity and location quotient have the most significant direct effect on innovation productivity. In addition, location quotient has a positive direct effect on the number of KIBS. Although racial diversity's direct effect is positive on all three actors of knowledge economy, its impact on KIBS and innovation is more significant when compared to the creative firms. Turning to the other indicator of tolerance, the number of bohemians in a census block group has a positive and significant direct effect (with almost equal effect size) on creative class and KIBS. Tolerance (including both bohemians and racial diversity) also has a positive indirect effect on innovation, which is mediated by creative class and KIBS.

	Activity Density	Transit	Bohemian	Job Growth	Racial Diversity	Amenity	Walk	Distance to CBD	Location Quotient	Creative Class	KIBS	
Direct	0.104	0.078	0.093	0.033	0.017	0.166	0.037	0	0	0	0	**Creative Class**
Indirect	0	0	0	0	0	0	0	0	0	0	0	
Total	0.104	0.078	0.093	0.033	0.017	0.166	0.037	0	0	0	0	
Direct	0.152	0.054	0.078	0.139	0.089	0.574	0	0.032	0.101	0.066	0	**KIBS**
Indirect	0.007	0.005	0.006	0.002	0.001	0.011	0.002	0	0	0	0	
Total	0.159	0.059	0.084	0.142	0.09	0.585	0.002	0.032	0.101	0.066	0	
Direct	0	-0.048	0	-0.027	0.103	0	-0.117	-0.071	0.121	-0.031	0.35	**Innovation**
Indirect	0.053	0.018	0.026	0.049	0.031	0.200	0	0.011	0.035	0.023	0	
Total	0.053	-0.029	0.026	0.021	0.134	0.200	-0.117	-0.06	0.157	-0.008	0.35	

Table 4: Standardized Direct, indirect and total; effects of the creative class, KIBS number, innovation count and other variables

This analysis found that the number of place quality amenities has a positive and significant direct effect on both KIBS and creative firm. The impact of place quality amenities on KIBS and creative firm are the biggest direct impact observed in this analysis. In addition, industry clustering and the number of place quality amenities indirectly contribute to the number of innovations and such amenities possess the biggest indirect effect on innovation among the observed indirect effects. Thus, by far, my analysis confirms the Well-established impact of industry clustering on innovation and KIBS. According to my analysis, one unit increase in industry clustering increases innovation by approximately 10%.

This analysis also tested whether local economic status has an impact on KIBS, creative industries location or innovation productivity. This stems from several critiques toward Florida's approach on creative class. It was widely discussed that not controlling for the local economies might result in an upward bias toward creative class (Scott, 2006). Addressing such criticism, I observed that job growth affects the size of creative class and KIBS but does not contribute to innovation productivity.

Turning to the two built environmental variables of greatest interest (walking and transit amenities), this study found that transit service quality and walkability contribute to a robust local knowledge economy through KIBS and creative class, but they have an adverse relationship to the innovation production of the STEM small firms. Walkability has a positive direct impact on creative class as well as a positive indirect effect on the rise of KIBS through creative class. Transit service quality has a significant and positive direct impact on creative class and KIBS but has an insignificant direct impact on innovation. It is also noteworthy that the total effect size of transit and walking amenities on creative class is relatively strong when compared to other exogenous variables. However, in sum, the total observed effects of walkability and transit on innovation are negative and unexpected, unlike their positive and significant impacts on the size of creative class and number of KIBS in the block group.

Discussion

My results suggest that an increase in the number of place quality amenities strongly improves knowledge-based economic vitality by increasing innovation productivity, creative class size and number of KIBS. While my results align with Canadian KIBS location behavior, with respect to creative industries, my results also couple with several cases from the U.S., EU, China and Australia (Florida, 2002b; Rao & Dai, 2017; Trip, 2007; Wood & Dovey, 2015). With regards to innovation, very few empirical studies have been carried out; However, my results align with the evidence from the U.S. (Hamidi & Zandiatashbar, 2018; Hamidi and Zandiatashbar, 2017a, Hamidi and Zandiatashbar, 2017b).

My findings also align with findings from prior studies about the importance of clustering through knowledge spillover, access to suppliers and a larger labor pool (Boschma 2005; Chatman and Noland 2011; Florida 2002b; Marshall 2009). In addition, the observed direct impact of industry clustering on innovation production and KIBS match those observed in earlier studies on Canadian KIBS (Shearmur, 2010). My analysis with respect to the impacts of tolerance are aligned with Florida (2002b) and Rausch and Negrey (2006) studies that show foreign born and bohemian residents contribute to robust local knowledge economy via increasing creative class size, number of KIBS and innovation production.

This study did observe the negative and significant impact of walkability on the innovation output of SBIR firms. The qualified firms for the SBIR grants are limited to high-tech and STEM based (among <10 industrial sectors) with fewer than 500 employees (Wallsten, 2001). These firms are seeking the SBIR grant in order to innovate new products and, as a result, grow. Their restricted resources, However, might limit them in their location decisions. Although walkable places (such as greenbelt new towns, neo-traditional subdivisions or urban and suburban centers like CBDs) are widely accepted to bring a variety of environmental and social benefits, one major drawback is their potential role in increasing property values and costs (Pivo & Fisher, 2011). Supported by the European and American studies (see more on Gilderbloom, Riggs, & Meares, 2015 and Nase, Berry, & Adair, 2013), innovative small firms might not be able to afford to locate in walkable places. This explanation is even more plausible as it supports the same findings from the impact of proximity to CBD in my analysis.

On the other hand, this study found that walkability significantly contributes to the creative class size and number of KIBS. Similar to the SBIR small firms, KIBS focus on the STEM-based economic activities. However, KIBS might not face the resource constraints as much as SBIR firms might and thus possibly can afford to locate in the walkable areas. This aligns with my findings that should KIBS strongly tend to locate close to CBDs and is consistent with the results of Canadian studies on the subject matter (Shearmur, 2010).

Transit quality (compared to walkability) more significantly attracts KIBS and creative class. These results confirm the role of transit quality as explained through Christaller central place theory and align with the evidence from Canada and China (Rao & Dai, 2017; Shearmur, 2010). Although transit quality possesses a positive direct impact on innovation, again this effect is insignificant. Considering the fact that office values increase as the result of proximity to transit stations, again it is possible that the small innovative firms could not afford to locate in the transit and pedestrian friendly neighborhoods (Nelson, 1999). Despite the general belief about the impacts of walkability and transit quality, the unaffordable property cost could be a barrier that calls for attention in future research.

Another interesting finding is that while creative industries do not have a significant impact on innovation production, KIBS significantly play a critical role. As evidenced in Müller, Rammer, and Trüby (2009), the key role of creative industries in innovation production is through the expansion of the skilled labor pool, innovation commercialization and marketing of the innovation products (Müller et al., 2009). This might not be the case for the SBIR innovative firms due to their small size and limited scope of works and products that usually do not lead to commercialization and marketing (Black, 2005). On the other hand, KIBS are very likely to collaborate in the innovation process with other firms, which makes the geographical proximity to KIBS a critical factor (Hertog, 2000). KIBS provide technical input and R&D services, which significantly contribute, to small firms throughout the innovation process.

Conclusion

This study is among the first national attempts to understand the relationships between indicators of robust neighborhood-level knowledge economy, transit service quality and walkability. The high quality of this research results from its unprecedented assemblage of the address level innovation and firm data for KIBS and creative industries for all block groups in the US; its unprecedented linkage of these data to build environmental industrial clustering, walking and transit data for these block groups; and its unprecedented use of SEM to estimate relationships between the built environment, knowledge and creative firms locations and innovation productivity.

Comparing my results from the U.S. to those from Canada, China, Austria, England or Australia, they suggest that the role of place in knowledge economy is not specific to a country, and the factors such as industry clustering, place quality amenities, diversity and tolerance play a critical role mutually in different countries (Bakhshi et al., 2008; Müller et al., 2009; Rao & Dai, 2017; Shearmur, 2010). Controlling for the direct, indirect and total effects, this study found that transit service quality increases the innovation productivity through attracting KIBS. Walkability also attracts KIBS through attracting creative industries.

These findings call for more innovation friendly place-based policies and plans. While federal organizations (like SBA) support innovation production, localities also can develop the complementary policies that enhance the proximity of STEM small firms or startups (like SBIR firms) to KIBS clusters which can be in form of a regional innovation hub zoning. According to my findings, such hubs are best to locate near CBDs, be walkable, and accessible via transit system and accommodate place quality amenities to satisfy KIBS' locational demands.

This study also did observe a negative significant impact of walkability and transit access on the innovation output of SBIR small innovative firms. This might be because walkability and transit access increase the property values and, therefore, make them unaffordable for small innovative firms (Pivo & Fisher, 2011). My findings on the impacts of walkability and transit access on innovation productivity in vulnerable small firms call for attention to the equity aspects of innovation-supportive urban developments.

This study offers several policy recommendations. My findings suggest that investments in the transportation systems should go beyond functionality and mobility concerns. Transportation infrastructures should be planned as ‘enablers’ for creative and knowledge firms. The imperative is to ensure a sound spatial coordination of land-uses and transportation infrastructures to create an ‘enabling’ physical environment for startups, small innovative businesses as well as other knowledge and creative industries. Planners and policymakers could ensure that the development/extension of a transit line is best leveraged by supporting land use and place making policies for empowering communities' artists, designers, non-profit cultural organizations as well as startups and innovative firms. Some of these policies are Well thought land-use plans near transit stations including an active street network, as well as zoning and incentives to accommodate educational services, co-working spaces, anchor institutions, and workforce development hubs.

Transportation planners could also draw upon location analysis for transit accessible areas in terms of their proximity to anchor institutions, creative firms, private R&D firms, high-tech employment sub-centers and creative clusters.

Knowledge economy is driving the growth of GDP and employment wage for the next tInty years. KIBS and knowledgeable workforce, as the drivers of knowledge economy, are central for the knowledge production. Transit service quality, walkable street networks, dense built environment that accommodate the urban amenities in the walkable distance are the location preferences of KIBS and knowledgeable workers. My findings call for innovation-supportive decision making on the transportation infrastructure investments.

Chapter 3_Essay 2: THE MISSING LINK BETWEEN PLACE AND PRODUCTIVITY? THE IMPACT OF TRANSIT-ORIENTED DEVELOPMENT ON THE KNOWLEDGE AND CREATIVE ECONOMY[2]

Introduction

Transit Oriented Developments (TOD) are presumed to contribute to the economic vitality of neighborhoods and cities (Renne and Wells 2005). However, apart from empirical evidence measuring the impact of stations on surrounding property values, research testing the relationship between TODs and broader economic development outcomes is still emerging (Nelson et al. 2015). Recent scholarship suggests that TODs are key to economic development by attracting creative and knowledge-based firms and workers as well as generating job growth in these sectors (Belzer et al. 2011; Nelson et al. 2015). Moreover, unlike the pre-recession and recession eras, jobs in TODs increased during the post great recession recovery, which indicates that TODs might also be key to economic resilience (Nelson et al. 2015).

TODs potentially attract workers, households, firms and provide greater accessibility to markets while creating dense, mixed-use built environments (Nelson et. al. 2015). TODs therefore may catalyze agglomeration dynamics leading to enhanced learning, innovation, and productivity across industry clusters (Chatman and Noland 2011). Further, these impacts are particularly important to knowledge and creative industries, which are key drivers in the knowledge economy.

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Like other clusters, creative and knowledge firms tend to co-locate in order to benefit from larger markets, thick and specialized labor pools. Additionally, knowledge and innovation spwellovers made possible through networking opportunities, spur industry growth and productivity (Scott 2006).

Knowledge intensive, creative firms and workers are particularly drawn to cities, because of their social and economic diversity, urban environments, and high quality amenities (Florida 2002). Diverse, mixed-use developments enabling the co-presence of innovative anchors, incubators, and start-ups as well as walkability and third places are considered vital for networking, knowledge exchange, and innovation spillovers (B. Katz and Wagner 2014). The attractiveness and 'authenticity' of a place is also assumed to provide the right creative milieu and buzz (Coll-Martínez & Arauzo-Carod, 2017; Currid & will iams, 2010).

TODs, often characterized by walkability, mixed-uses, and accessibility to regional markets, would seem to provide built environments that best support innovation and productivity for creative and knowledge firms. Indeed, recent empirical evidence supports this hypothesis. Drawing on the Small Business Innovation Research (SBIR) database, scholars found more award-winning innovations Ire developed in dense, mixed-use and walkable neighborhoods (and regions) that also benefit from high-quality transit service (Hamidi and Zandiatashbar 2018, 2017a, 2017b; Hamidi, Zandiatashbar, and Bonakdar 2018; Zandiatashbar and Hamidi 2018). However, despite the popularity of policies focused on creative placemaking, there remains less than conclusive evidence tying the above place-based characteristics of TODs with the attraction of creative and knowledge based industries, much less how the built environment impacts firm productivity (Evans 2009).

Using national datasets on industry and transit station characteristics, this article addresses this gap by exploring the relationship between TOD built environments and creative and knowledge industry firm sales volume. Using cluster analysis, this study creates a typology of transit station areas differentiating TODs from other transit station development types. I then use Propensity Score Matching (PSM) to create paired matches of creative and knowledge firms located within a 1.25- mile network distance of different station types. The PSM includes indicators for the agglomerative forces and firm characters denoting a combination of firm's inputs according to the production function framework. Within this framework, firm's productivity is defined as the level of obtainable sales volume from combination of the firm's inputs (Aigner and Chu 1968). This allows us to estimate the average treatment effect of TOD station area type on firm sales volume, which indicates firm's productivity after the PSM controlled for the firm's inputs. The results suggest that dense, diverse TODs positively impact creative and knowledge firm sales volume. The paper concludes with a discussion regarding how planners can integrate land use regulations and policies that support TOD with placemaking and knowledge-led economic development strategies in order to maximize economic benefits.

What is a TOD?

Many U.S. cities and regions are turning to TOD as a key smart growth strategy (Dwell, 2008). As a result, planners use specific policies and land-use regulations to cultivate or shape TODs such as mixed-use zoning (Grant 2002), density bonuses (Freilich 1998), performance zoning, interim zoning, floating zones, minimum density classifications (Cervero, Ferrell, and Murphy 2002; Gabbe 2016), planned unit developments, transfer of development rights (S. M. White and McDaniel 1999), and adaptive reuse (Riggs and Chamberlain 2018). However, not every development in a transit station area can be characterized as a TOD (Kamruzzaman et al. 2014; Renne and Ewing 2013). Scholars define TODs as compact neighborhoods centered around transit with efficient land use diversity, density, street connectivity, and walkability that encmyage residents, workers, and customers to ride mass transit more than driving their cars. Therefore, residential and employment density (Cervero and Gorham 1995; Kamruzzaman et al. 2014; Pollack et al. 2014; Renne and Ewing 2013), land use diversity (Cervero and Gorham 1995; Kamruzzaman et al. 2014; Renne and Ewing 2013; Vale 2015), and walkability or street connectivity (Brown & Irner, 2011; Renne & Ewing, 2013; Vale, 2015; Irner, Brown, & Gallimore, 2010) have become the most frequently utilized factors for classifying station types.

In the only existing national study categorizing transit station area developments, Renne and Ewing (2013) classified rail station areas into three categories of TOD, hybrids and Transit Adjacent Developments (TADs). They adopted a "minimum benchmark definition of TOD" approach and utilized a point-based system to measure density, land use diversity, and walkability in 0.5-mile Euclidean distance buffer for stations. Accordingly, density parameter receives one point if the station precinct has greater than 30 jobs or residents per gross acre; diversity parameter receives one point if the station precinct does not have 100% of its land uses as either residential or commercial; and lastly, the walkability parameter receives one point if the station precinct average block size is less than 6.5 acres. Summing these points, TAD = 0 or 1 point, Hybrid = 2 points and TOD = 3 points. Using another scoring method, (Pollack et al. 2014) found four groups of Transit-Oriented, Transit-Supportive, Transit-Related, and Transit-Adjacent areas.

Addressing the shortcomings of point-based scoring methodology, later studies began utilizing cluster analysis as a more systematic and objective approach. Kamruzzaman et al. (2014) used a 2-stage cluster analysis and included residential and employment density, public transport accessibility levels, land use diversity, and street connectivity measured through intersection density and cul-de-sac density. They identified five types of station neighborhoods - urban TODs, activity center TODs, potential TODs, TADs, and traditional suburbs. Vale (2015) used six place-index measurements including residential density, employment density by four sectors, and degree of functional mix and seven node-index measurements. He employed cluster analysis in identifying six station area types including urban TODs, balanced TADs, suburban TODs, undersupplied transit TODs, unbalanced TODs, and future TODs. Using cluster analysis, Scheer et al. (2017) also classified station area types based on three built-environment factors—density, land use diversity, and walkability into three groups including TOD, hybrid, and TAD. Using a half-mile network distance catchment area within eight U.S. regions, Scheer, Ewing, Park, & Khan (2017) found 107 station to be TAD, 382 Ire Hybrid, and only 60 Ire TOD.

My work, therefore, contributes to this area of research in several ways. First, most studies of this kind cover only one or a few regions (i.e. Sheer et al. 2017; Kamruzzaman et al., 2015; Vale, 2015), while my research includes all stations in the U.S. Second, I employ cluster analysis, which has clear advantages over a scoring methodology (i.e. Pollack et al., 2014; Renne and Ewing, 2013). Third, existing studies mainly rely on straight-line catchment areas versus network distance from each station (i.e. Vale, 2015; Renne and Ewing, 2013). To address this gap, my analysis uses network distance, which unlike straight-line distance, uses the street network to identify a catchment area. Similar to several previous studies I also use built environmental measures which can determine the travel behavior of residents (Handy, Cao, and Mokhtarian 2005), thereby creating more direct implications for planning practice (Scheer et al. 2017).

Economic Developments Outcomes of TODs

TOD is theorized to affect economic outcomes through regional productivity and resilience, agglomeration economies, and localized property market impacts (Banister 2012). A significant amount of research has focused on the latter with scholars exploring TOD's impact on residential housing prices and to a lesser extent, commercial real estate values (Golub, Guhathakurta, and Sollapuram 2012). However, this impact varies by city-region (Hamidi, Kittrell, and Ewing 2016; Mohammad et al. 2013). In Dallas, home values rose by 32% when located within one-quarter mile of a Dallas Area Rapid Transit (DART) station, while values only climbed 2.5% in Buffalo MetroRail areas using the same proximate distance (Garrett 2004; Hess and Almeida 2007). In addition, TODs function as critical nodes in regions (Bertolini and Spit 2005) and aid in balancing jobs and housing across a metro area (Cervero 1989). TOD is also found to support regional resilience (Martin 2011; Nelson et al. 2015). Nelson et al. (2015); for instance, found evidence that metropolitan areas with Light Rail Transit (LRT) systems Ire more resilient during the Great Recession and experienced greater gains after the recession compared to the nation as a whole. Recently, scholars have focused on TOD's relationship with agglomeration economies. Starting with Marshall (1890a), it has long been understood that clustering benefits firms through "external economies of scale", as a result of shared labor pools, specialized suppliers, and common infrastructure. It is likely that TOD developments support these dynamics. By attracting households, workers and firms in close proximity to one another. TODs could increase local diversity and density of firms, enlarge access to markets, reduce transportation costs and increase an area's human capital (Chatman and Noland 2011). TODs could also generate further benefits by enabling efficient matching of jobs and skills leading to less employee turnover and termination rates (Credit 2017; Chatman et. al. 2016; Chatman and Noland 2014, 2011).

TODs may offer further advantages to industry clusters through place-based characteristics. Porter (1990), Storper (1993), and Scott (2003); among others, have built on agglomeration theory to analyze clusters as dynamic, concentrated sites of competitive yet complementary industries. Specifically, they have emphasized the importance of social relations made possible through geographic proximity. Co-location enables networking, tacit knowledge exchange, and trust building which gives firms competitive advantage by quickly accessing new technologies and industry strategies (Gertler, 2003; Hardwick, Anderson, & Cruickshank, 2013; HoWells, 2002; Inkpen & Tsang, 2005; M. E. Porter, 2000; Scott & Storper, 2003). Location is particularly important to knowledge and creative industries (Clare 2013; Florida 2002b; Grodach et al. 2014; Murdoch, Grodach, and Foster 2016). Creative and knowledge industries rely on a rich eco-system of large firms, SMEs (Small and Medium Enterprises), and freelancers, characterized by intense networking and collaboration (Comunian 2011; Dovey et al. 2016). As workers thrive in buzzy, creative environments, scholars argue that these industries prefer places with walkability, mixed uses, third places, and particular aesthetic qualities to support sociality (Clare 2013; Drake 2003; Durmaz 2015; Smit 2011).

As TODs are more spatially bounded through dense street networks and often include mixed-use zoning incorporating spaces for consumption, professional services, and aesthetic enhancements, they may be Well positioned to attract creative and knowledge firm’s worker force and support high quality networking. There is some evidence to support this as scholars have found a positive relationship between transit stations, transit use, and networking (Chatman and Noland 2011; Murphy 2000). Also, TODs have been found to attract knowledge, creative, service and retail firms relative to firm starts in other areas (Belzer et al. 2011). Credit (2017) likewise found that compared to auto-centric areas, transit station proximity in Phoenix predicted an 88% increase in knowledge firm startups compared to service and retail sectors, which experienced a 40% and 28%, increase, respectively. Other research concluded that most TOD areas gained jobs in some knowledge and creative economy industries, adding more than $100 billion in wages capitalized over time (Nelson et al. 2015).

Despite this research, However, there is little evidence whether TODs influence firms' sales volume. Indeed, drawing together research on transit and economic development, agglomeration economies, and the creative economy, several questions emerge. The first is whether business owners will gain more return for their investment in TODs. Property values are relatively higher in TODs (Debrezion, Pels, and Rietveld 2007; Hamidi, Kittrell, and Ewing 2016; Mohammad et al. 2013). Consequently, if business owners want to locate in a TOD, they would need to invest more in property costs. Yet it is theorized that firm productivity might increase in a TOD due to clustering and networking (Nelson et al 2015). Moreover, the majority of studies on economic outcomes of TODs have not properly controlled for station areas' built environments (Chatman et. al. 2016; Nelson et al.

2015). This research contributes to these debates by testing whether creative and knowledge firms exhibit stronger sales volume as a result of locating in a TOD. As such, planners and policymakers will be able to better understand the linkages between land use, transit and knowledge-based economic development in order to maximize economic benefits while simultaneously realizing social and environmental advantages associated with smart and creative city development policies.

Research Process and Methods

To assess the relationship between TOD and knowledge-based and creative firms' sales volume, I first have to control for other factors that may also influence these relationships. Therefore, my study consists of three steps. First, I employ cluster analysis to classify rail station areas based on density, diversity, and walkability as three built environment characteristics extensively suggested by the literature (Scheer et al. 2017; Renne and Ewing 2013). Second, from my national micro-dataset of creative and knowledge firms, I select firm samples located in each station area type. I utilize propensity score matching (PSM) methodology to determine the impact of TOD on firm sales volume by matching similar firms located in three different station types using six explanatory variables - number of employees, sectoral classification, square footage area of firms, firm headquarter status, job accessibility via transit, and accessibility to firms of similar industrial character within 20-minute driving time (i.e., matched firms in TOD- TAD, TOD-Hybrid, and Hybrid-TAD). Finally, this study compares sales volume for the firms in different station area types and computes the average treatment effect of being located in a TOD. I consider TOD stations as the treated group, and TAD and hybrid stations as the control groups in my major matched firm pairs. My data come from the Center for Transit- Oriented Development's TOD database, which includes about 5,145 rail transit stations in the United States (including existing, planned and proposed stations before 2011). My study also employs disaggregated point-level business data from the Esri Business Dataset (EBDS) and includes 219,844 knowledge and creative firms in the U.S.

Step 1. Station Area Classification: Cluster Analysis

The built environments associated with transit stations fall within a Transit-Oriented to Transit Adjacent (TAD) spectrum, rather than a simple dichotomous scale. Furthermore, there is no agreement regarding the ideal built environments for TOD. As such, identifying TOD stations and distinguishing them from other transit development styles such as TAD is a difficult but important research step. To this end, I first identify the transit catchment areas depending on the mode people use to travel to the transit station. For instance, the catchment area will be larger for those bicycling compared to those walking, and larger for bus travel versus bicycling.

However, areas with a pedestrian friendly urban design and housing and employment density, can extend the catchment area beyond one mile (Canepa 2007). As a result, Patheram et al. (2013); among others, question the conventional measure of the 0.5-mile catchment. Although a pedestrian can cover 0.5 mile in 10 minutes with constant walking speed of about 3 mph, pedestrians who tolerate slightly longer walking times and faster speeds, can extend a transit catchment area to one mile or beyond. Alternatively, a transit catchment area could also be determined by identifying how far the market responds to a station. I adopt a distance measure drawn from Patheram et al (2013), which found that Salt Lake TRAX transit stations impacted rental property values falling within the 1.25 mile of transit stations, but no further. Hence, my catchment area includes all firms and census blocks whose centroids fall within the 1.25-mile network distance of transit stations.

Drawing on similar methodologies used in previous studies (Atkinson-Palombo and Kuby 2011; Scheer et al. 2017) this research uses a hierarchical clustering algorithm with average distance measures to classify station area types based on three built environment factors – activity density, land use diversity, and street network design (Table 5). This approach allows us to group existing station areas based on their actual built environmental characteristics, rather than hypothetical criteria of TOD or TAD. Three built environment variables are standardized to make the variance across variables equal. Even though earlier studies have classified transit stations in three categories (TOD, TAD and Hybrid) (Renne and Ewing, 2015), their classifications are based on certain thresholds. To validate these findings, I attempt to determine the optimal number of clusters in my dataset using *NbClust* package in R 3.4.2 software (Charrad et al. 2014).

Indicator	**Description**	**Data Smyce**
Activity Density	Station area activity density (sum of population and employment of census blocks - in which their centroids are in the transit station catchment area - divided by land area in square miles)	Computed in the study using the 2011 LEHD and 2010 census data
Land Use Diversity	Entropy Index (based on net acreage in different land use categories including retail, entertainment, health, education, and personal services. It ranges from 0, where all developed land is dedicated to one use, to 1, where developed land is evenly divided among uses)	Computed in the study using the 2011 LEHD
Street Network Design	Intersection Density (sum of all type of intersections divided by land area in square miles)	Computed using TomTom 2007 database

Table 5: Built Environment Variables used for Station Area Classification

Table 6 shows the results of hierarchical clustering for 5,145 rail stations in the U.S. The first cluster (n=260) is titled ‘TAD’ because it has the lowest level of density, diversity, and intersection density. The second and largest cluster (n=4734) is classified as ‘Hybrid’ which has a high entropy index and medium levels of activity and intersection densities. The third group (n=151) is named ‘TOD’ as these stations exhibit the highest levels of activity density, diversity of uses, and intersection density.

Cluster type	Number of Stations	Activity Density in 1000 (/sq.mi.)		Entropy Index		Intersection Density (/sq.mi.)	
		Mean	S.D.*	Mean	S.D.	Mean	S.D.
TAD	260	12.09	12.89	0.34	0.16	101.62	70.86
Hybrid	4734	26.48	28.38	0.84	0.11	175.06	82.43
TOD	151	270.50	84.19	0.82	0.15	260.94	59.39
TOTAL	5145	32.91	51.70	0.81	0.16	173.86	84.23

* Standard Deviation

Table 6: Cluster Analysis Result and Descriptive Statistics

My sample firms are those located within a 1.25-mile network distance from only those stations that have been functioning since before 2011. I allot individual firms to their nearest stations based on network distance in order to assign the station type.

The Hybrid group has the largest number of firms (n=132,370), followed by the TOD (n=25,124) and TAD (n=2,811) station types (Table 7). Table 7 shows that sales volume is highest in TOD stations, followed by Hybrid and TAD. On average, TAD firms have the highest number of employees, Hybrid firms have larger office spaces and are more likely to be a headquarter (HQ) or subsidiary, while TOD firms have better job accessibility by transit and better access to firms in similar industries.

Table 7: Firm Characteristics by Station Area Types: average, ANOVA, and Chi-squared Analysis

Cluster type		**TAD**	**Hybrid**	**TOD**	**Total**	**F-statistics**	**X^2–statistic**
Number of stations		170	3,357	137	3,664	-	-
Number of firms		2,811	132,370	25,124	160,305	-	-
Sales volume		3,085.0	3,150.4	4,304.0	3,330.1	19.09***	-
Number of employees		22.83	14.72	20.80	15.82	41***	-
Job access		0.17	0.20	0.28	0.21	1199***	-
Automobile access		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Headquarter status	HQ	45	1,309	339	1,693	-	272.51***
	Branches	359	13,469	2,138	15,966		
	subHQ	28	1,159	435	1,622		
	None	2,379	116,433	22,212	141,024		
Square footage of office area	Less 2.5k	645	35,646	1,241	37,532	-	10013***
	2.5-10k	937	45,556	6,096	52,589		
	10-40k	699	28,618	10,094	39,411		
	Over 40k	530	22,550	7,693	30,773		

***: p<0.01, **: p<0.05, *: p<0.1

Step 2. Creative and Knowledge Economy Sample Firm Selection: Propensity Score Matching

Researchers have been widely using PSM to overcome issues resulting from the nonrandom assignment of individuals to treatment groups in the evaluation of social programs (Oakes and Johnson 2006). These kinds of studies are often centered on observational data, which introduces confounding variables into the study because of non-random assignment. As a result, there are likely systematic difference between individuals in the treatment group versus those in the control group that must be controlled for in order to assess the actual impact of the treatment. These same concerns apply to studying diverse firms located in a range of places. For example, firms in suburban regions might be smaller (or larger) than those in downtown areas, and subsequently produce less (or more) profit. Subsequently, the observed difference in outcomes (i.e., sales volume) between firm groups may be caused by these confounding firms characteristics as opposed to being the result of the treatment. In my case, the treatment is the impact of being located in a TOD catchment area. PSM addresses this issue by allowing us to generate a treatment group of firms located in TOD station types as well as a control group, which includes similarly matched firms located in TAD areas. The propensity score is therefore defined as the conditional probability of assignment to a particular treatment given a vector of observed covariates (Rosenbaum and Rubin 1984). I developed a binary logit model to estimate propensity scores using the subsample of firms located in TOD (treatment) and non- TOD (control) station areas. The propensity score matching was implemented in R 3.4.2 using the MatchIt package.

I identify creative and knowledge economy firms using a list of North American Industry Classification System (NAICS) codes. Considering this research is interested in the role place plays in firm sales volume, industry data is most relevant for my study. In order to identify creative economy firms, I follow the definition developed by Markusen et al. (2008) and use 85 distinctive NAICS codes active in four categories including the production and distribution of cultural goods, the production and distribution of intellectual property and cultural educational services (Markusen et al. 2008, 40–41). For the knowledge economy, I include 51 sectors by adopting the Brookings' two criteria, which are as follows (Muro et al. 2015, 21):

_ R&D spending per worker must be in the 80th percentile of industries or higher and exceed $450 per worker.

_ Firm workers with a high degree of STEM knowledge should be above the national average, or 21 percent of all workers.

In addition to the firms' sectoral categories, I chose six firm characteristics as independent variables – firm headquarter status, number of employees, square footage area of firms, job accessibility via transit, and accessibility to firms of similar industrial character within a 20 minute driving time – as confounding factors in sales volume outcomes based on the following three economic frameworks. First is the production function that relates the level of obtainable sales from each feasible combination of the firm's inputs, which are generally labor and capital

(Aigner and Chu 1968). Second is the capital and corporate structure framework measured by employment size and assets (e.g. land) (Fischer, Heinkel, and Zechner 1989), and the firm's status in the corporate structure (e.g. headquarter vs. plants) (Gao, Ng, and Wang 2011). While these two frameworks estimate the firms' sales volume in the short run, the third framework - economies of scale - indicates the parameters through which the scale of production increases in the long run through its accessibility to and benefits from shared labor pools, customer markets, specialized suppliers and knowledge as a result of intra-industry firm proximities (Marshall 1890b). Table 8 includes information for the abovementioned six indicators. Next, I match each firm in TOD station types with those in non-TOD based on the propensity score. Caliper length of 0.03 is used for matching, meaning that for a treatment observation, I use a match in control observations whose propensity scores are within 0.03 of the score of the treatment observation (Austin 2011).

Indicator	Description	Data Smyce
Dependent Variable		
Firm Sales Volume	Modeled sales volume of the business. ($000s)	EDBS 2016
Independent Variables		
Headquarter status of the firm	Categorical variable indicating whether the business is a headquarter, branch, subsidiary headquarter or none of the above.	EBDS 2016
Employee Number	Number of employees at firm.	EDBS 2016
Square Footage Area	Estimated Square Footage of firm. (A = 0 - 2,499; B = 2,500 - 9,999; C = 10,000 -	EDBS 2016
Job Accessibility Via Transit*	Measure of jobs within 45-minute transit commute, distance decay (walk network travel time, GTFS schedules) weighted.	Smart Location Database from Environmental Protection Agency (2010)
Sectoral Categories	Creative Economy Sectoral Categories: Cultural Goods Production Cultural Goods Distribution Intellectual Property Production and Distribution Educational Services Knowledge Economy Categories: T-KIBS	ESRI business analyst
Auto-accessibility*	By using Arc GIS network analysis, I developed a 20-minute driving buffer for each firm. I then included the creative and knowledge economy firms following the same NAICS codes and measured the percentage of firms located in the buffer divided by the total number of firms (all sectors) in the region.	Computed by Network Analysis on EDBS 2016

*. Number of jobs/facilities in a 20-minute auto trip (and a 45-minute transit trip) have been the performance measures for evaluating accessibility in both academia and practice (Boisjoly and El- Geneidy 2017). These measures stem from the observed median travel time of the employees and also is predicted by economic theory (Ewing et al. 2015). While people/employees are willing to take up to a 20-minute auto trip (and a 40-minute transit trip)-since the generalized cost per trip is lower at these locations-beyond this time would be considered long and would be avoided if possible (Levine et al. 2012).

Table 8: Descriptions and sources of model variables

The PSM generates 4,874 firm matches (2,437 in total) in the TOD-TAD pair, 31,710 matches in the TOD-Hybrid pair, and 5,622 matches in the TAD-Hybrid pair.

Step 3: Sales Volume Comparison Analysis

The key and final goal of this study is to compute the "true" impact of TOD station area type on firms' sales volume. Once the matching is complete, I calculate the average treatment effects (ATE) of station area type on sales volume. The ATE is computed as the mean sales volume of the matched TOD firms minus those of the matched non-TOD firms. In multiple case comparisons, not simply one treatment and one control, the propensity scores can be estimated separately for each pair of control and treatment groups (i.e., TOD-TAD, TOD-Hybrid, and TAD-Hybrid) (Lechner 2002). For each pair of locations, I use t-test analysis to assess sales volume differences between the firms in my subsample located in each specific transit station area type.

I conduct three t-test analyses. My first model is an analysis of the sales volume differences for both knowledge and creative economy firms. The results suggest that while both TOD and hybrid station types positively impact firm sales volume, stations with higher levels of population density, walkability, and mixed uses have the strongest impact on firms. Table 5 shows that after matching (i.e. controlling for firm characteristics), TOD firms, on average, sell 6,538 more units than their counterparts in TAD station types and the difference is statistically significant. Likewise, in the matched samples, TOD firms sell 2,158 more units than Hybrid firms. Lastly, the difference between Hybrid and TAD firms are also significant at 0.05 probability level. Using the results of sales volumes between the three pairs of station area types, I can also estimate the impact on sales volume corresponding with the changes made to station areas or as a result of a firm's move from one station type to another. For example, if a firm moves from a TAD to a Hybrid station type, or theoretically, if a city changes a TAD to a Hybrid station type by increasing its development density, land use mix, or street connectivity, the average firm is expected to sell more products. If the firm moves to a TOD, or the station area is developed into a TOD, the firm is expected to have even higher sales volume. Cumulatively, from TAD to TOD, a firm is estimated to have significantly higher sales volume.

My second and third models test the impact of TOD stations on knowledge and creative economy firms separately. As shown in Table 5, the results suggest that although all firms benefit from increasing activity, density, and walkability, knowledge economy firms may benefit more than creative economy firms. As shown in Table 5, knowledge economy firms located in TOD stations with the highest level of activity, density, and walkability outperform knowledge firms located in Hybrid and TAD areas. This same dynamic exists, albeit not quite as strongly, when comparing Hybrid with TAD stations. Although average firm sales are greater in Hybrid compared to TAD station, the results do not reach statistical significance.

The last model analyzes the relationships between station area type and creative economy firms. The impact on sales volume is much stronger for the creative economy firms compared to knowledge economy firms when comparing the firms in TOD with the firms in Hybrid areas, but not stronger than in the other pairs. As indicated in Table 5, increasing levels of density, activity and industry diversity clearly have positive impacts on firm sales volume of creative industry. The movement from TAD to Hybrid and TOD, and Hybrid to TOD all reflect greater gains in sales volume when compared to knowledge industry firms, However only two latter pairs are at statistically significant levels.

Table 9: Differences in sales volume between station area types after matching

	Area type pair	Sales volume of treatment group	Sales volume of control group	ATE (difference)	t-statistic
Knowledge Economy and Creative Economy Firms	TOD(treatment)-TAD(control) (n=4,874)	9,711.1	3,173.1	6,537.9	-5.03***
	TOD(treatment)-Hybrid(control) (n=31,710)	5,447.7	3,289.9	2,157.8	-5.67***
	Hybrid(treatment)-TAD(control) (n=5,622)	5,335.2	3,085.0	2,250.2	-2.86***
Knowledge Economy Firms	TOD(treatment)-TAD(control) (n=1,950)	9,810.9	3,865.6	5,945.3	-3.01***
	TOD(treatment)-Hybrid(control) (n=13,052)	5,687.1	4,230.4	1,456.7	-3.46***
	Hybrid(treatment)-TAD(control) (n=2,812)	4,646.4	3,968.1	678.4	-0.96
Creative Economy Firms	TOD(treatment)-TAD(control) (n=2,514)	5,357.3	2,385.3	2,971.9	-3.70***
	TOD(treatment)-Hybrid(control) (n=15,782)	5,613.7	2,686.0	2,927.7	-7.45***
	Hybrid(treatment)-TAD(control) (n=2,666)	2,576.7	2,248.5	328.2	-0.74

***: p<.01, **: p<.5, *: p<.1 (T-test results)

Note: After the PSM, the sum of the number of knowledge economy and creative economy firms is not same as the total number of knowledge and creative firms. This is because I used caliper length of 0.03 as a threshold, meaning that the one-on-one matching may fail when two closest observations are not within 0.03 of the propensity score.

Discussion

According to my national transit station typology analysis, only 3% of stations areas are TODs. Almost 92% of station areas are hybrid and the remaining 5% are TADs. My findings differ from previous attempts using similar methodologies to classify rail station areas. However, the majority of these studies are limited to either one or a few regions (Atkinson-Palombo and Kuby 2011). In the only existing national study, Renne and Ewing (2013) presented the same three- station typology (TOD, Hybrid and TAD). However, they found 37% to be TOD, 31% to be Hybrid and 32% to be TAD among the 4,400 rail stations (Renne and Ewing, 2013). The disagreement in my findings is not surprising. Renne and Ewing (2013) used a 0.5-mile straight- line distance while I used a 1.25-mile network distance from each station to identify station catchment areas. In addition, they adopted a system that scored station areas for residential density, land use diversity and walkability; I employed cluster analysis for that purpose.

Hybrid stations, as the largest category among the three station types, are home to more than 82% of the knowledge and creative firms located within my station catchment areas, while TODs are home to more than 15% of firms in my sample. In contrast, firms in TOD station types are mostly branches, have the biggest sales volume and strongest job accessibility via both automobile and transit while occupying large office areas. These results suggest that TODs could actually serve as vital anchors, fueling the broader creative and knowledge economy.

Based on my analysis of built environmental attributes for each station area type, my results confirm that TODs are significantly denser, have a higher degree of mixed land uses and exhibit a stronger street connectivity. For example, my 151 TODs are 8 times denser and have 1.5 times stronger street connectivity than the total average. However, in terms of land use diversity, there is not a significant difference between TODs and hybrids. This shows the potential of hybrids to be transformed into TODs by increasing density and street connectivity. Using my station classifications, policy makers can identify hybrid stations that have the greatest potential for increased density and street connectivity by incorporating land use and zoning policies to facilitate such transformations.

I also found significantly higher sales volume in hybrid than TAD stations for both knowledge and creative firms. While locating in TODs might be unaffordable for small knowledge startups due to higher property values, policy makers might leverage their resources to incentivize knowledge firms to locate in hybrid station areas. Conventional economic development strategies such as tax abatements, development assistance and other incentives (Blakely and Leigh 2009)could be employed as well as strategies focused specifically on the creative and knowledge industries such as placemaking efforts (Pancholi, Yigitcanlar, and Guaralda 2018; Smit 2011), the creation of live-work, co-working and other collaborative, creative spaces (Gadwa and Markusen 2009), the development of flagship cultural institutions (Grodach 2010) and siting of knowledge-based anchors through collaborations with universities or larger innovative firms (Comunian, Taylor, and Smith 2014).

Despite the fact that relatively smaller number of knowledge and creative firms are located in TODs, such firms experience significantly higher sales volume relative to comparable firms in TADs and Hybrids. These findings provide additional empirical evidence to business owners and policymakers that there is likely a higher return in investment by locating a firm in a TOD compared to other station types. This is also the case for the Hybrid-TAD comparison in firm sales volume. My findings support the literature stating that knowledge and creative firms are more productive in dense, walkable and diverse places because they create the right kind of buzzy environment for networking, learning, and collaborating (Murphy 2000; Storper and Venables

2004; Currid and will iams 2010b; Katz and Wagner 2014; Hamidi and Zandiatashbar 2018; Zandiatashbar and Hamidi 2018). It is worth noting that TOD stations on average are home to more headquarters and larger firms, which may act as anchors in these creative and knowledge-based clusters. These stations also likely benefit from geography as they are within closer proximity to highly skilled workers and similar industries (Bathelt, Malmberg, and Maskell 2004; Porter 2000). In other words, TOD's street network, mixed uses and density of activity only form part of the dynamic constellation of factors influencing firm productivity.

Conclusion

TODs share many of the place-based characteristics presumed to support creative and knowledge firm productivity such as accessibility, walkability and mixed uses. Yet there is little research on the relationship between TOD and the creative and knowledge economy (Credit 2018). Furthermore, there is scant evidence on the economic impact of TOD beyond their influence on surrounding property values. Considering, However, the research on TOD, agglomeration economies, and creative clusters, there is reason to believe that these types of developments would have broader economic impacts. This study attempts to provide insight into these relationships by first categorizing TOD station areas by activity diversity, land use diversity and street network design; and second, by testing how these different place-based environments impact creative and knowledge firms' sales.

The results of this study indicate that creative and knowledge firms do benefit significantly from locating in TOD station areas. As such, the research suggests planners should integrate TOD oriented policies and regulations with creative and knowledge-based economic development strategies to maximize impacts. For example, while TOD areas currently exist in different neighborhood types (i.e. CBDs, Urban/Town Centers, and Urban Neighborhoods); one neighborhood type could also be an innovation-hub TOD. The addition of an innovation-hub TOD to other networked TOD areas could provide the infrastructure to building more resilient and innovative regional economies. Planning for innovation-hub TODs should be based on strategic land use plans, zoning, and incentives to accommodate educational anchor institutions, workforce training centers, co-working spaces, creative and knowledge-led startups, accelerators, and incubators (Katz and Wagner 2014) in addition to existing TOD oriented land use and policy regulations such as mixed use zoning, density bonuses, reduction of parking ratio regulations, placemaking, adopting district plan, Adaptive Reuse Ordinance (ARO) and active transportation design. Such planning efforts can draw upon the successful examples of these regulations. For instance, state-enabled density bonus and incentives successfully facilitated high-density multifamily developments in station areas which in combination with adaptation of district specific plans spurred TOD growth in Los Angeles (Gabbe 2016).

Additional incentives could include economic development grants for startups, worker training tax credits, and location-based venture capitals. Municipalities should also plan for "upzoning" their hybrid station areas, which already accommodate such services and uses. Accessibility to other universities, CBDs, and airports is critical for this type of TODs in order to allow the inflow of educated workers and local and global customers; hence, transit services and routes should be planned accordingly.

There are already several cities integrating TOD and knowledge economy policies. For instance, the city of Richardson, TX recently adopted a plan to develop the Collins/Arapaho Innovation-hub TOD. In addition to anchoring the site with the University of Dallas' Life Science Center, the plan includes attracting talented labor and support active transportation through higher- density development of TOD apartments in close proximity to the rail station ("Collins/Arapaho Transit-Oriented Development and Innovation District Study | Richardson, TX" 2018). An innovation-hub

TOD with a distinct design regulation is the Rainier Beach Food Innovation District (FID) in Seattle, WA. This example plans to boost cross-cultural food innovation and encourages high-density mixed-used developments with designation of rooftop greenhouses (Crowley 2015) . To boost networking and exchange, the Rainier Beach Urban Farm also works with the festival square as the district's core public urban center for culinary events and markets. Moreover, Towerside Innovation District in Minneapolis, MN is another example with off-site district wide parking to reduce driving in this 370-acre planned TOD district. This Innovation TOD also includes a signature urban center/plaza, which actively hosts hackathons, high-tech startup competitions, entrepreneurship boot camps, and grassroots art festivals. Minnesota Innovation Park, which is anchored by an educational institution, is another example, which includes public space in its planning. In addition, municipalities can implement the Adaptive Reuse Ordinance (ARO) as a placemaking policy to support signature urban center/plaza or post- industrial mixed uses. ARO encourages building reuse through regulatory exemptions to reduce Vehicle Mile Traveled (VMT) and help cultivate TOD growth, as well as preserve the historic resources in downtown Los Angeles (Riggs and Chamberlain 2018).

Although the research supports the relationship between TOD and creative and knowledge-based economic development, the findings open up several lines of research for further inquiry. More research is needed to understand the role for regional characteristics such as local economy and climate amenities on knowledge and creative firms' sales volume. It remains unclear how much of an impact anchor firms and geographic location have on cluster productivity, relative to other station characteristics such as walkability, density, and mixed uses. Further, although the findings provide support for the theory that TODs increased firm economic activity by creating conducive conditions for face-to-face interaction, this study did not directly test the role of social networking. Future research could also disaggregate the creative and knowledge industry clusters to determine if these relationships vary by industry and firm size. Research that is able to tease these dimensions apart by tracking dynamics over time would help to clarify the relationships regarding place characteristics, firm location preferences, and agglomeration benefits in addition to the role the built environment plays in networking, learning, and generating buzz.

Furthermore, networking and learning are often tied to technological and innovation spillovers, as opposed to sales volume measures. Future research could unpack these different outcomes. The inclusion of research on TOD into discussions of the knowledge and creative economy also presents an opportunity for a more holistic perspective regarding the economic impact of both transit development policies and the presence of creative and knowledge industries. Currently, research on the creative and knowledge economy tends to focus on either place-based change in the form of urban revitalization or regional economic impacts. Considering the role transit can play in encouraging agglomeration and increased firm sales, TODs may enable clusters of creative and knowledge firms to develop and become networked across regions, leading to broader economic gains. Understanding the role TOD plays in knowledge and creative economic productivity, suggests that there is a need for revisiting location theories in light of a restructured economy. Therefore, future research might attempt to rearrange the hierarchical system of urban centers and weight TOD areas accordingly. Furthermore, since both TOD and the presence of creative and knowledge industries can lead to more localized revitalization outcomes; it would be productive to study these dynamics concurrently.

As cities and regions transition away from an industrial economy, policymakers and planners are continually looking towards the importance of strengthening its knowledge and creative based industries. Although economic geographers and planners have long recognized the value of place in attracting creative and knowledge firms and workers, there has been little attention towards the role TOD could play in these dynamics. This research suggests that there are untapped synergies between TOD and creative and knowledge economies. By integrating planning efforts, planners and policymakers may be better equipped to create places that not only benefit industry clusters, but also provide the framework for a more robust regional innovation ecosystem.

Chapter 4_Essay 3: HIGH-TECH FIRMS AND THEIR DIFFERENT TAKES ON TRANSIT AND WALKING AMENITIES; EXPLORATIONS FROM THE U.S. GEOGRAPHY OF HIGH-TECH ZONES.

Introduction

Pioneered by Marshall (1890), there has been a growing interest in identifying the industry clusters as the ‘‘geographic concentration of interconnected companies and institutions in a particular field’’ (M. E. Porter 1998). Both policy makers and academics have paid extensive attention to this subject as industry clusters play a fundamental role in forming the regional innovation systems, production systems, job destinations as well as the spatial structure of the regions (Asheim, Smith, and Oughton 2011; Koo 2005; M. E. Porter 2000; Scott and Storper 2003). Since 1980s and during the transition to knowledge-based economy, much of the current literature in this subject focuses on the formation of innovation and its impact on planning and economic development (Audretsch and Feldman 2004; Granpayehvaghei et al. 2019; Hamidi and Zandiatashbar 2017; Hamidi, Zandiatashbar, and Bonakdar 2018; Zandiatashbar et al. 2019; Zandiatashbar and Hamidi 2018). The fact that high-tech industries generate innovation and could also catalyze innovation in other firms, make them key actors of the innovation ecosystems in cities as well as their regions (Madanipour 2013; Shearmur 2012).

Despite the key role that high-tech industries play in innovation systems and their growing share from national employment, Gross Domestic Product (GDP), and global economy, there has yet to be micro-scale quantitative research to identify the location of high-tech industry clusters or in the other words high-tech zones (Muro & Liu, 2017). Existing research fails to quantify the spatial concentration of high-tech firms at the local level while mostly focuses on the neighboring counties or regions with the strong high-tech economy using the measures of sectoral concentration of high-tech economic activities (Edward Feser, Sweeney, and Renski 2005; Koo 2005; M. Porter 2004). Additionally, these studies have been inconsistent in their definition of high-tech industries and yet to control for the Research & Development (R&D) intensity of the output and input. For instance, a number of studies included only ten sectors (Wu et al., 2016), while others included more than 100 industries (Edward Feser, Sweeney, and Renski 2005).

The growth of knowledge economy industries in the U.S. has been accompanied by the need for revisiting the traditional land use and development patterns stemming from the locational demands of knowledge-intensive firms. Local, regional and national policymakers seek to understand these needs and differences in order to attract, support and grow the tech industries as new engines of economic growth. Understanding these locational patterns also leads to more effective smart growth management strategies. In the regions that are facing a high growth of tech industries, firms' locational decisions play a critical role in shaping regional developments (Cooke and Leydesdorff 2006; Scott and Storper 2003).

Despite early concerns regarding the 'placelessness' of knowledge-intensive activities, location remains significant for high-tech industries (Relph 1976). Large urban centers with a high concentration of knowledge-based industries, high quality talent, easy access to suppliers and markets are winners in the new global economy (Glaeser and Sassen 2011; Sassen 2016). The high-tech businesses also are also composed of different industries with different locational behaviors which, in turn, could raise different infrastructures, development patterns, and accessibility needs (Fallah, Partridge, and Rickman 2013).

Despite the importance of high-tech economy in shaping regions, research analyzing the role of transportation infrastructure in the location decisions of high-tech firms is limited (K. N. Credit 2018). This is surprising considering the attention paid to transportation infrastructure in other academic and policy discussions of economic development strategies (Aschauer 1989; Banister 2012; Bröcker and Rietveld 2009; Elburz, Nijkamp, and Pels 2017). Empirical literature on transportation and high-tech firms is emerging from the agglomeration and placemaking frameworks, concluding that transit and walking amenities would attract these firms and increase their productivity. This line of research emphasizes the role of transit access and walkability as amenities that could expand the labor and customer markets, support further face-to-face encounters and knowledge exchange while also attracting the specialized human capital who are the major runners of high-tech economic engine (Bakhshi, McVittie, and Simmie 2008; K. N. Credit 2018; Florida 2002b; Hamidi and Zandiatashbar 2017; Hamidi, Zandiatashbar, and Bonakdar 2018; B. Katz and Wagner 2014; Shearmur 2010; Zandiatashbar et al. 2019; Zandiatashbar and Hamidi 2018).

While there is a consensus on the preference for transit and walking amenities by tech industries and knowledge workers, there is less clear agreement on the extent to which these advantages differ across tech sectoral categories. For instance, IT industries are becoming increasingly less place-based as a result of increasingly relying on self-employed, part-time, and flexible workforce (Audirac, 2005; Delgado, Porter, & Stern, 2015; Feser, SIeney, & Renski, 2005;

Maggioni, 2002). On the other hand, the new logistic revolution extends the demand for road and air mobility as the response to the need for fast processing and distribution of time-sensitive high-tech production and goods (Appold and Kasarda 2013; Kasarda 2000).

While some industries might prefer walkable and transit accessible locations, this might not be significant for others (Maggioni 2002). Yet, there are very few empirical studies quantifying these differences. Further empirical analyses are needed to inform the debate on the accessibility needs of high-tech firms while accounting for their specialized differences. Understanding these differences would lead to more informed and evidence-based sustainable transport policies and decisions.

This study seeks to address these shortcomings and offers a new perspective by defining the geography of high-tech zones at the most disaggregated scale for 52 largest metropolitan areas in the U.S. My analysis includes quantifying and measuring the location of high-tech zones and developing a sectoral typology for each zone. First, I identify the U.S. geography of high-tech zones as the local spatial peaks of high-tech economic activity by employing tessellation grid, Principal Component Analysis (PCA), spatial statistics techniques, and the micro-level firm dataset from the ESRI Business Analyst Dataset (EBAD). Second, I develop a sectoral typology for these high-tech zones using Herfindahl-Hirschman Index, Location Quotients and cluster analysis. Lastly, I analyzed high-tech industries location behavior in their local spatial clusters using a series of Multinomial Logit Regressions and estimating the marginal effects of the transportation infrastructures. My models thus test whether different types of high-tech firms have significantly different transportation infrastructure preferences. For this analysis I used the firm-level micro dataset provided by Esri Business Dataset, WalkScore, TransitScore, network-based distance to nearest freeway ramp and the region's primary hub airports as the measures of local, regional and (inter)national accessibility.

First, my findings about the geography of high-tech zones provide better understanding of the high-tech landscape of the U.S. large regions. My findings show that these regions are widely diverse in terms of the number and the spatial distribution of their high-tech zones. For instance, Los Angeles metro area, (widely found to have a polycentric spatial structure (Giuliano et al. 2007, 2015; Gordon and Richardson 1996; Gordon, Richardson, and Wong 1986) has the highest number of zones while in New York, San Francisco, and San Jose metro areas, the high-tech economy is concentrated in fewer, but stronger, zones.

Furthermore, I found that the high-tech economy in the U.S. highly depends on professional services (i.e. the firms primarily designed to support other businesses such as consulting, legal services, facilities support services, computer services, engineering and architectural services, and placement services (Delgado, Porter, and Stern 2015) and most of the high-tech zones have diverse firms from multiple high-tech specializations. However, the large manufacturing high-tech industries like aerospace have notably fewer zones mostly in the regions where the aerospace industry has had a strong presence such as Dallas-Fort Worth metro area in Texas.

Lastly, my findings show that the major regional airports are anchoring the high-tech zones with diverse specializations. Such results call for more research on the role of major airports within large metropolitan areas in supporting multiple high-tech employment hubs.

Drawing upon the Multinomial Regression analyses, confirm that high-tech firms have significantly different preferences for transportation infrastructures. While professional services (architecture/engineering) seek walkable and transit accessible zones in proximity to CBDs, the IT, aerospace, and pharmaceutical sectors prefer easy access to freeway systems, which likely stem from the specifications of these industries. For example, the success of high-tech professional services highly depends on their ability to attract skilled workers who are drawn to transit and walking amenities. Moreover, dense and walkable CBDs enhance frequent face-to-face encounters, tacit knowledge exchange, and physical access to the local market area (Granpayehvaghei et al. 2019; Hamidi and Zandiatashbar 2017; Hamidi, Zandiatashbar, and Bonakdar 2018, 2018; Zandiatashbar et al. 2019; Zandiatashbar and Hamidi 2018). On the other hand, IT industries need fast distribution of products, just-in-time delivery and use online interactions for exchanging codified knowledge instead of face-to-face meetings. These needs could justify their desire for proximity to air and road infrastructure (Appold and Kasarda 2013; Audirac 2005; Kasarda 2000; Maggioni 2002). My findings also confirm the formation of airport-adjacent industrial clusters in response to the global and e-commerce economy. Accordingly, these results show that major airports anchor employment centers and providing a spatial focus for unrelated and diverse high-tech firms.

Firm Clusters: Concepts and Measures

It is widely accepted that firms benefit from clustering through “external economies of scale”. Some of the benefits include shared labor pools, specialized suppliers, and shared infrastructure. Furthermore, the empirical efforts have confirmed that companies in clusters grow more strongly and innovate more rapidly than non-clustered companies and that clusters could attract start-ups and result in spinoffs (Swann et al., 1998; Baptista, 2000; Klepper, 2007). These impacts have found to be principal in the knowledge-based economy, hence, a dominant focus of knowledge economy research has been on the importance of co-location and clustering. The concept of industry clustering was further developed by Porter (2000) as the “geographic concentrations of industries interrelated by knowledge, skills, inputs, demand and/or other linkages.”

According to more recent studies, clustering is particularly beneficial for knowledge-based firms that rely on face-to-face contacts, social networking, and tacit-knowledge exchange (Asheim, Smith, and Oughton 2011). Existing literature largely supports the notion that knowledge-based firms do cluster, that firms benefit from co-location, and that clusters are key to regional economic growth (Delgado, Porter, and Stern 2015; Koo 2005; M. Porter 2004). This line of research is also supported by the creative class and creative city narratives, pointing to the importance of particular place-based built environmental qualities such as walkability, mixed land use and urban aesthetics (Florida 2002b). This combination of research exploring the geography of knowledge-based industry clusters and creative city narratives has led to the implementation of knowledge-based urban development policies such as location incentives as well as placemaking strategies such as innovation districts (Asheim, Smith, and Oughton 2011; Grodach et al. 2014; Hamidi, Zandiatashbar, and Bonakdar 2018; B. Katz and Wagner 2014; L.

F. Katz and Krueger 2016; Wood and Dovey 2015; Zandiatashbar et al. 2019). Mostly, these policies advocate for certain infrastructures and urban developments in such clusters. The basic frameworks for making such policies are agglomeration economies and placemaking strategies that seek to address the high-tech businesses and talented human capital's location preferences (B. Katz and Wagner 2014). For instance, transportation infrastructure is often integrated in these policies as walkability and access to public transit are known as key characteristics of knowledge-led placemaking strategies (L. F. Katz & Krueger, 2016; Pancholi, Yigitcanlar, & Guaralda, 2018; Yigitcanlar, O'connor, & Isterman, 2008).

While the existing literature largely supports the notion that knowledge-based firms do cluster, (Delgado, Porter, and Stern 2015; Koo 2005; M. Porter 2004), there is little consensus on where knowledge-based firms cluster. Several scholars such as Grodach et al., (2014) believe that innovation districts are in dense and urban CBDs, other researchers identify different spatial clustering patterns based on firm size, geographic context, and specific industries and institutions in the cluster. Currid and Connolly (2008), for example, classify knowledge clusters in three types including the CBD-based clustering, dispersed regional clustering and specialist places (Currid and Connolly, 2008). Similarly, Madanipmy (2013) has identified a range of innovation clusters beyond live-work-play developments such as campus-like technology parks, and geographically distributed 'science cities'.

These studies are mostly theoretical and rely on limited observations. Very few empirical attempts on identifying the clusters of knowledge-based firms are highly aggregated and have employed the measures of sectoral concentrations (e.g. Gini coefficient, Ellison and Glaeser, or

Location Quotient) for the counties or regions (Edward Feser, Sweeney, and Renski 2005; Koo 2005; Kopczewska 2018). Another widely noted weakness of using such measures is their "a-spatial" property in that it treats space as discrete units and, hence, do not account for the spatial clustering patterns of high-tech industries (Alecke, et. al. 2006). Existing literature offers little or no empirical analyses at the micro-scale that identify high-tech clusters using spatial techniques and explore their sectoral and development types.

This need for identifying the geographic concertation of high-tech businesses is more plausible both in academic and policy developments areas as these clusters play a foundational role in forming the regional innovation systems, production systems, and urban and economic development, given the rise of knowledge-based economy (Asheim, Smith, and Oughton 2011; Delgado, Porter, and Stern 2015; M. Porter 2004; M. E. Porter 2000; Scott and Storper 2003). The present study addresses these gaps in the literature by identifying the local high-tech zones in the large U.S. regions using spatial statistical technique and developing a sectoral typology for them at the most disaggregated level using a firm-level micro dataset.

The Geography of Innovation

A dominant focus of knowledge economy research has been on the importance of co-location. Pioneered by Marshall (1890), it is widely confirmed that clustering benefits firms through "external economies of scale", as a result of shared labor pools, specialized suppliers, and common infrastructure. The concept of industry clustering was further developed by Porter (2000) as the "geographic concentrations of industries related by knowledge, skills, inputs, demand and/or other linkages."

According to more recent studies, clustering is particularly beneficial for knowledge-based firms that rely on face-to-face contacts, social networking, and tacit-knowledge exchange (Asheim, Smith, and Oughton 2011). Existing literature largely supports the notion that knowledge-based firms do cluster, that firms benefit from co-location, and that clusters are key to regional economic growth (Delgado, Porter, and Stern 2015; Koo 2005; M. Porter 2004). This line of research is also supported by the creative class and creative city narratives, pointing to the importance of particular place-based built environmental qualities such as walkability, mixed land use and urban aesthetics (Florida 2002b).

This combination of research exploring the geography of knowledge-based industry clusters and creative city narratives has led to the implementation of knowledge-based urban development policies such as location incentives as well as placemaking strategies such as innovation districts (Asheim, Smith, and Oughton 2011; Grodach et al. 2014; Hamidi, Zandiatashbar, and Bonakdar 2018; B. Katz and Wagner 2014; L. F. Katz and Krueger 2016; Wood and Dovey 2015; Zandiatashbar et al. 2019). Transportation infrastructure is certainly implicated in these policies in that walkability and access to public transit are often key characteristics of knowledge-led urban development placemaking strategies (L. F. Katz &

Krueger, 2016; Pancholi et al., 2018; Yigitcanlar, O'connor, & Isterman, 2008).

While the existing literature largely supports the notion that knowledge-based firms do cluster, that firms benefit from co-location (Delgado, Porter, and Stern 2015; Koo 2005; M. Porter 2004), there is little consensus on where knowledge-based firms cluster. Several scholars such as Grodach et al., (2014) believe that innovation districts are in dense and urban CBDs, other researchers identify different spatial clustering patterns based on firm size, geographic context, and specific industries and institutions in the cluster. Currid and Connolly (2008), for example, classify knowledge clusters in three types including the CBD-based clustering, dispersed regional clustering and specialist places (Currid and Connolly, 2008). Similarly, Madanipmy (2013) has identified a range of innovation clusters beyond live-work-play developments such as campus-like technology parks, and geographically distributed 'science cities'. This line of research suggests that the geography of innovation is more diverse and more data driven research is needed to identify the geography and typology of high-tech zones in the U.S.

Theorizing High-tech Firms' Accessibility Needs

Much of literature in recent years has emphasized the role of quality-of-life factors in location decisions by the creative class including walking and transit amenities (Chatman and Noland, 2011; Credit, 2017; Hamidi et al., 2018; Hamidi and Zandiatashbar, 2018; Nelson et al., 2015; Zandiatashbar and Hamidi, 2018). Walking and transit ridership are widely known as the important aspects of the lifestyle of millennials and university graduates who are relatively more car-free (Hamidi and Zandiatashbar, 2018). Millennials own 12% fewer cars than previous generations, are less likely to be licensed drivers, live in denser places, and have on average twice the level of transit access to jobs as compared to older generations (Klein and Smart 2017).

While the demand for a highly specialized workforce justifies the need for walking and transit amenities, there exist several types of high-tech firms which may not benefit as much from place-based amenities for their workforce recruitment. These tech sectors (i.e. IT, communication technologies industries) have footloose economic activities and flexible production systems and prefer a more part-time and flexible workforce. Their workforce often joins organizational teams remotely using online spaces, which makes these new economic activities increasingly personalized rather than place-based (Audirac, 2005). On the other side of the spectrum, there are high-tech sectors such as service providers (i.e. engineering/architectural/drafting services, Ib-developer/software publishers, and private Research and Development (R&D) labs) that produce immaterial commodities like knowledge-based professional and consultation services. These industries do not require production and distribution of goods or logistic mobility, but rather need accessibility to local markets for their services.

Therefore, the high-tech location preferences for local, regional, and (inter)national mobility infrastructures are likely more diverse as a result of different specializations, logistics, customers, labor markets, and land utilization (Maggioni, 2002). Certain types of high-tech firms, such as pharmaceutical research organizations or medical device firms, consist of more homogenous occupations which mostly require a very specialized workforce (Mellander 2009). Other high-tech firms, such as large manufacturing businesses, employ a range of occupations (i.e. accountants, software engineers, traditional manufacturing jobs, health-care assistants, and service jobs at the food court), and for some of these occupations do not necessarily need a highly specialized workforce (Kimelberg and Nicoll 2012). While regional accessibility helps large high-tech manufacturing firms to have access to a wider labor market supporting their diverse occupational demands, the success of other firms often depends on their ability to attract and retain quality skilled workers.

High-tech firms' different customer markets also might lead to different transportation preferences for local, regional and (inter)national accessibilities. Financial consultants, legal services, or headquarters of IT or aerospace companies resonate with Sassen's (1991) concept of global cities in which nations are firmly connected and draw on a global market of customers. As a result, air mobility and online interaction are becoming increasingly important modes of transaction and transportation. Airports, on the other hand, are also expanding their functionality beyond air mobility by adding a variety of businesses and commercial functions into passenger terminals (i.e. magazine shops, fast food outlets, boutiques, VIP rooms, co-working spaces, etc.) or on the landside (i.e. hotels, offices, conference and exhibition centers) to serve these needs (Kasarda, 2000). However, local accessibility might matter more for some high-tech industries, such as support services, computer services, engineering and architectural services, and placement services, due to the importance of service to the local customers. Accordingly, per Christaller's Central Place Theory, these industries tend to locate in the walkable and transit accessible CBDs in order to have access to a wider customer market area. These industries are considered a high-order service category, which, unlike low or medium order services that locate frequently and homogenously, need to concentrate in central cities in order to cover a wider market area (Zandiatashbar and Hamidi, 2018).

As a result of these differences, the high-tech industries could have different accessibility needs and favor different types of urban development. For instance, manufacturing and service-based high-tech industries might not be attracted to locations with similar characteristics as they have different the labor and customer markets, logistic mobility needs and land acquisitions (Audirac 2005; Maggioni 2002). On the other hand, understanding these differences are critical as high-tech industries play a pivotal role in regional economic developments. Just in recent years, a substantial portion of regional and local policy developments have dealt with attracting and accommodating the high-tech industries. These efforts could be taken in tandem with s smart growth management strategies if further empirical analyses reveal these different needs. Despite the above-mentioned differences and the critical role of high-tech industries, most of the existing empirical literature on transportation and high-tech firms is emerging from the agglomeration and placemaking frameworks. These studies generally conclude that transit and walking amenities would attract these firms and increase their productivity (Bakhshi et al., 2008; Hamidi et al., 2018; Hamidi and Zandiatashbar, 2018; Katz and Wagner, 2014; Zandiatashbar and Hamidi, 2018). However, these findings mostly look at high-tech firms as a whole, and there is yet to be enough empirical efforts that look into different high-tech categories and their differences in order to identify the different accessibility needs of high-tech industries.

Research Process and Methods

This research draws upon a 3-step research design in order to identify the high-tech zones in the U.S. large regions, measure their sectoral specializations and analyze the high-tech firm location behavior in these zones. The first step includes tessellation sampling and hotspot analysis region by region in order to identify the high-tech zones. Once the zones are identified, the second step uses Herfindahl-Hirschman (HH) Index, Location Quotient (LQ) and clustering technique to identify the sectoral specializations of the zones. Ultimately, the last step includes analysis of the high-tech industries' location behavior using the multilevel multinomial logit regression and marginal effect estimation. The study uses the address-level firm datasets provided by the Esri Business Analyst Database (EBAD) which includes the 6-digit NAICS for identifying the high-tech industries. This data also allows the tessellation sampling at the most disaggregated level rather than using the census pre-defined geographical boundaries.

Using the U.S. Business Labor Statistics (BLS) definition of high-tech firms, an address-level data-set of firms, and one-by-one regional analysis, I addressed three methodological shortcomings in previous studies. First, the criteria used for identifying high-tech industries failed to control for the R&D intensity of the output, which has led to inconsistency across the studies. For instance, some studies included only ten sectors (Wu, Nager, and Chuzhin 2016), while others included more than 100 industries (Edward Feser, Sweeney, and Renski 2005).

Second, the unit of analysis in these studies is not finer than county level boundaries, which limits detecting local specialized high-tech clusters. Studying the impacts of firms on their surrounding urban developments and locational attributes require identifying specialized clusters at a finer geography. Further, the census defined geographic units such as census block groups and census tracts are widely varied in terms of size and land area, which is a limitation for a contiguity-based spatial analysis. I used a firm-level dataset and tessellation sampling (hexagon cells) to address these issues (see Figure 1). Lastly, I ran the spatial statistical analysis on a one-by-one basis for all Metropolitan Statistical Areas (MSAs) in my sample to high account for the sources of heterogeneity.

Sample

In this study, I analyzed high-tech firms in 52 largest regions in the U.S. with more than one million population. According to the EBAD 2016 dataset, nearly 71% of the U.S. high-tech firms are located in these regions. Additionally, the selection of large MSAs accounts for the characteristics associated with the region's size such as land value, land availability, labor and customer markets while these factors could influence the micro-level firm location behavior (Anas, Arnott, and Small 1998; McDonald 1989).

Furthermore, my spatial statistics analysis focuses only on the urbanized portions of the MSAs since only 7% of high-tech firms scattered in the rural areas with little or no clustering patterns. The Census Bureau's urban-rural classification is used to remove rural areas from the analysis. Based on the 2010 Census definition, an urban area would comprise a densely settled core of census blocks that meet minimum population density requirements, along with adjacent territories containing non-residential urban land uses as well as territory with low population density included to link outlying densely settled territory with the densely settled core. To qualify as an urban area, the territory identified according to criteria must encompass at least 2,500 people, at least 1,500 of which reside outside institutional group quarters. Ultimately, the study area included 314,303 high-tech firms.

My classification of high-tech industries is borrowed from the U.S. BLS methodology, which classifies high-tech firms in three levels based on R&D intensity:

Level I: 5 times greater than average employment share in the STEM fields

Level II: 3 to 4.9 times greater than average employment share in the STEM fields

Level III: 2 to 2.9 times greater than average employment share in the STEM fields

The BLS also adjusts this classification based on the R&D output. About 10 out of 14 sectors in level I produce R&D outputs while only 4 out of 11 sectors in level II, and no sector in level III produce R&D outputs (Heckler, 2005). For this analysis, I applied the BLS level I definition of high-tech firms. Table 10 presents these industry sectors.

Table 10: high-tech specializations categorized by inter-industry linkages based on co-location patterns, input-output links, and similarities in labor occupation (Delgado et al., 2010; Heckler, 2005).

Specialization

1) Information Technology and Analytical Instruments

This category consists of information technology and analytical products such as computers, software, audio visual equipment, laboratory instruments, and medical apparatus as well as the standard and precision electronics used by these products (for example, circuit boards and semiconductor devices). This category includes:

Industries: NAICS 5112: Software Publishers, NAICS 3341: Computer & Peripheral Equipment Manufacturing, NAICS 3344: Semiconductor Manufacturing, NAICS 3345: measuring, electromedical, and control instrument manufacturing

2) Aerospace Devices

Establishments in this category are manufacture aircraft, space vehicles, guided missiles, and related parts. This cluster also contains firms that manufacture the necessary search and navigation equipment used by these products. This category includes:

Industries: NAICS 3364: Aerospace products/manufacturing, NAICS 334511: Navigational equipment

3) Bio-pharmaceutical

Establishments in this category produce complex chemical and biological substances used in medications, vaccines, diagnostic tests, and similar medical applications. This category includes:

Industries: NAICS 3254: Biopharmaceutical Products, Biological Products, Diagnostic Substances

4) (Professional) Services

Firms in this category include services primarily designed to support other businesses. This includes corporate headquarters. Professional services such as consulting, legal services, facilities support services, computer services, engineering and architectural services, and placement services. This category includes:

Industries: NAICS 5182 & 5415: Data Processing, system design and computer services, NAICS 5413: Engineering Services, Architectural and Drafting Services

5) Communications Equipment and Services

This category involves goods and services used for communications. This includes cable, wireless, and satellite services, as well as telephone, broadcasting, and wireless communications equipment. This category includes:

Industries: NAICS 3342: Communications equipment manufacturing, NAICS 5179: Other telecommunications

6) Education and Knowledge Creation

This category includes research and development institutions in biotechnology, physical sciences, engineering, life sciences, and social sciences. This category includes:

Industries: NAICS 5417: Research Organization

Furthermore, coupling this definition with a micro-level firm dataset, I Ire able to detect the most disaggregated high-tech zones using the process explained in the next sections.

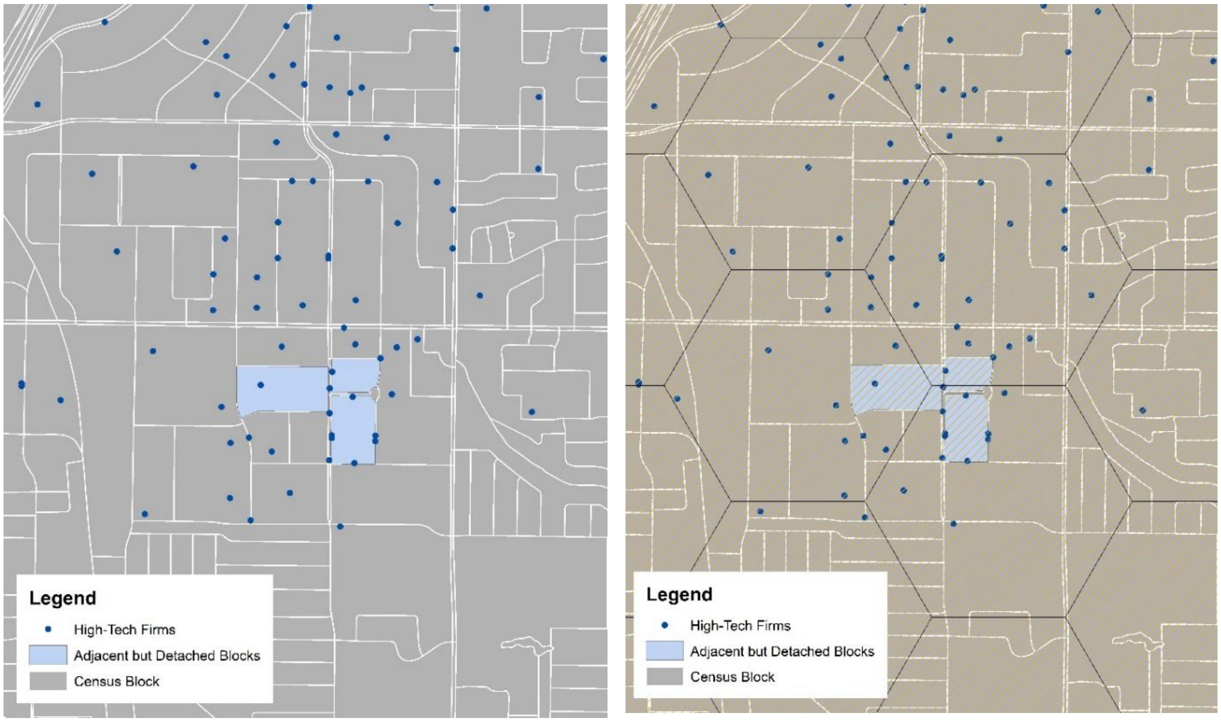
Phase 1- Identifying the Geography of High-tech Zones

I applied spatial modeling technique for identifying the location of high-tech zones. The spatial statistics have been mostly used to detect the monocentric or polycentric spatial structures of the regions, changes in the location of CBDs or to locate employment sub-centers (Hajrasouliha and Hamidi 2017; Hamidi 2015). For instance, using Getis-ord Gi* statistics, Hajrasouliha and Hamidi (2017) identified the location of CBDs and employment sub-centers for all MSAs in the U.S. While the priori application of spatial statistics in location analysis of high-tech clusters is limited, Feser and his colleagues (2005) used Getis-ord Gi* statistics to identify the clusters of U.S. counties that encompass strong high-tech employment. In the same line, Koo (2005) used the local Moran's I statistics to examine the geographical patterns of knowledge-based clusters in U.S. counties using employment and patents.

The two major spatial statistics are Local Moran's I and Getis-Ord Gi. The Local Moran's I identifies cases of positive (HH, LL) and negative (HL, LH) spatial autocorrelation, while the Getis-Ord Gi* identifies cases with positive autocorrelation with a more straightforward definition and readily interpretable output (Getis and Ord 1992). As I Ire interested in all clusters of positive values, I chose local Getis- Ord Gi* statistics for identifying the clusters of high-tech industries.

Further, the previous studies used census-defined units for their spatial analyses while using contiguity spatial Weights for neighboring units (Feser et al., 2005). These units suffer from the size inconsistency, which is a limitation for a contiguity-based spatial analysis. I used firm-level dataset and tessellation (hexagon cells) to address the inconsistency issues of census boundaries. Using the tessellation-sampling method in ArcGIS, I divided the urbanized portion of each region to hexagon cells. Each cell has an area of 0.3 square mile, which equals to the average land area of the U.S. urbanized census block groups. Figure 3 illustrates how hexagon cells could overcome the shortcoming of census block boundaries and offer a consistent unit of analysis for the spatial Weighting attributes.

Figure 3: Unit Size Inequality of Census Boundaries and Application of Tessellation



In terms of the input variables for the spatial statistics analysis, previous studies on high-tech employment clusters or sub-centers have employed different approaches. Total employment, residual of regressed high-tech employment on total employment, patent numbers, high-tech plant counts, employment density, number of firms and employment-to-population ratio measures are among the widely used variables (Fallah, Partridge, and Rickman 2013; Edward Feser, Sweeney, and Renski 2005; Hajrasouliha and Hamidi 2017). To obtain a more comprehensive measure, I used Principal Component Analysis (PCA) and defined a new factor (HT) which is an index composed of the number of high-tech employees and high-tech firms. I estimated HT value for each cell, which includes factor loadings of 0.71 for employment and 0.71 for firm number. The index derived from PCA has an eigenvalue of 1.41, which explains 70.75% of variance.

Using the HT factor for every hexagon cell, I estimated the local Getis-Ord Gi* with queen neighboring (in queen neighboring, units are neighbor if they have common borders or corners) for each MSA in the study area. This analysis compares the sum HT value of a hexagon's neighbors (local sum) to the overall sum HT value of an MSA. When the local sum is higher than the total sum, and that difference is too large to be the result of random chance, there would be a statistically high chance that this group of cells is a hotspot. Ultimately, I identified clusters of cells with high HT values (hotspot) as high-tech zone candidates.

The Getis-Ord Gi* is defined as:

$$G_i^* = \frac{\sum_j^n \quad w_{ij} x_j}{\sum_j \quad x_j} \tag{3}$$

Where:

The numerator is the sum of all values in the neighborhood of i.

The denominator is the sum of all values in the study area.

Gi* is the percentage of the total sum found in the neighborhood of i

I also used the False Discover Rate (FDR) adjustment to control for the presence of "overlapping subsets" in the Gi* analysis. This overlapping is caused because the data used to produce a local statistic at block group i is also used to produce the statistics at block group j (a nearby block group). The FDR procedure controls for the expected proportion of incorrectly rejected null hypotheses or "false discoveries." I used the 'spden' and 'psych' packages in R for estimating the Getis-Ord Gi* and PCA analysis estimating the *HT*. Ultimately the cells with Z-Value >= 2.4 at 99% level of confidence Ire found the effective attributes between the regions and used to collect the cells composing the high-tech clusters. The results of hot spot analysis are presented for the regions with the highest Z-Value representing the hexagons with the strongest high-tech clusters.

Phase 2-Sectoral Typology of Zones

I used the widely applied measure of industrial diversity (Herfindahl-Hirschman (HH) Index) and specialization concentration, Location Quotient (LQ), to develop the sectoral typology for the zones. The HH Index is widely used in the literature as the absolute measure of sectoral concentration or diversity (Kopczewska 2018). HH index ranges from 0 to 1 with 0 indicating the even distribution (e.g., of employment among the firms) and 1 indicating the extreme concentration (e.g., of employment in few or single firm) (Kopczewska 2018).

I computed two HH indices for each zone using the following formula to account for both firm number and employment size. Different specializations demand different employment sizes for their operation. Also the number of firms is widely cited as an indicator of urbanization externalities which occurs as the results of agglomerative forces (Jacobs 1969).

Formula (4): Herfindahl-Hirschman (HH) Index

$$HH = \sum_{i=1\ldots6}^{I} (A_{ic}/A_c)^2$$

A_{ic}=Number of Employees and Firms in High-tech Category *i* According to the table 1

Ac=Total number of High-Tech Employees/Firms

Next, I used a hierarchical clustering algorithm with the average distance measure to classify zone types based on the two continuous HH indices. I used the NbClust package in R 3.4.2 software to identify the optimal number of clusters. NbClust provides 22 validation indices of clustering including the Calinski and Harabasz and Silhouette indices to identify the optimal number of clusters (Charrad et al., 2014). Table 11 presents the two classes of zones (mono and diverse) obtained from the cluster analysis.

Table 11: Cluster Analysis Result and Descriptive Statistics

Cluster Type	Number of Zones	HH Emp Index		HH Firm Index	
		Mean	S.D.*	Mean	S.D.
Mono	263	0.75	0.16	0.61	0.15
Diverse	367	0.43	0.11	0.43	0.09
Total	627	0.57	0.21	0.50	0.15

S.D.=Standard Deviation

I found 263 out of 627 high-tech zones to be mono-specialized. In the next step, I identified their specializations using Location Quotient (LQ). LQ is the local measure of concentration for each zone (see Formula 3). The LQ value of greater than 1 indicates the concentration of industrial category in the zone; the LQ value of greater than 1.25 indicates that the industry sector is a potential exporter and the LQ value of loIrs than 1 indicates an underrepresentation of industrial sector in the zone (Kopczewska 2018).

Formula (5): Formula for Location Quotient

$$LQ = {}^{e_i/e_t}\Big/_{E_i/E_t}$$

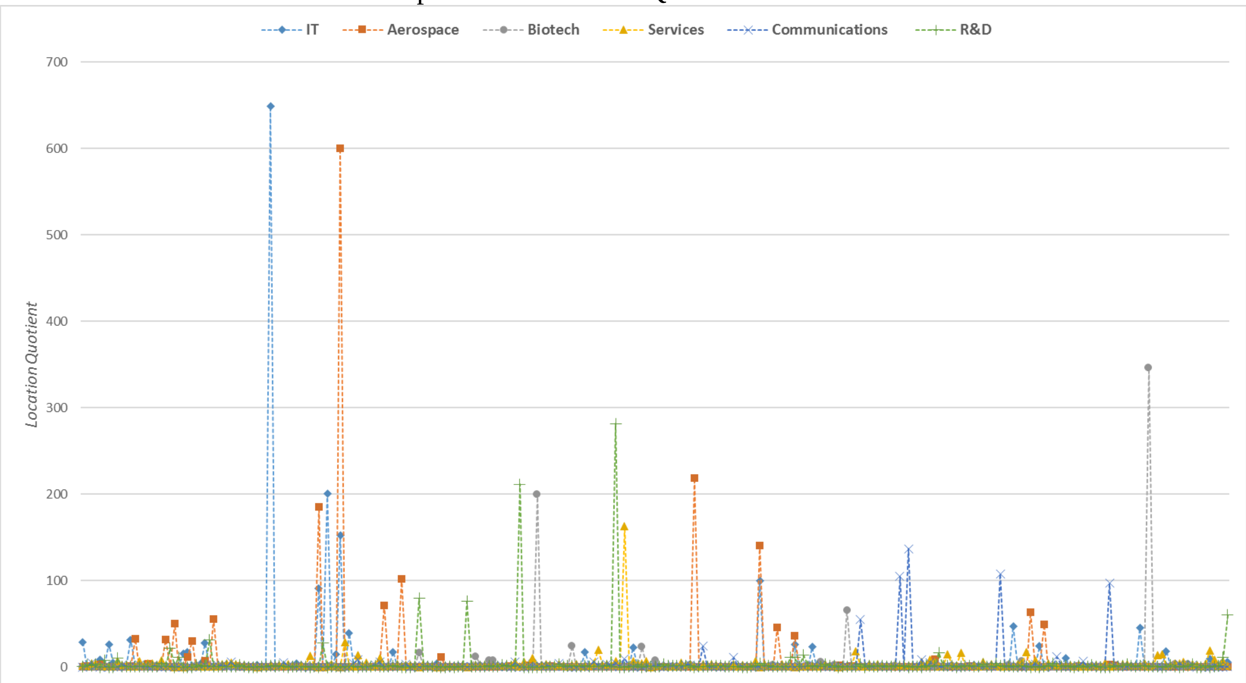
e_i=Zone’s Number of Employees in High-tech Category i According to the table 1
e_t=Zone’s total employment

E_i=Region’s Number of Employees in High-tech Category i According to the table 1
E_t=Region’s total employment

The result of LQ computation for the six categories of high-tech industries (discussed earlier in table 10) are presented in Table 12. The LQ values computed for the monopolized zones have skewed distributions and generally, for each zone LQ of one category has a remarkably higher value than the rest (see the chart in Table 12).

The results of LQ computation for the six categories of high-tech industries (see Table 1) are presented in Table 12. I computed the LQ measures for the 263 monopolized zones. I found that for each zone, the LQ of one category has a remarkably higher value than the other sectorial categories (see the chart in Table 3).

Table 12: Distribution Chart Descriptive Statistics of LQ



Variable	Mean	S.D.*	Min	Max
IT	6.7	43.9	0	648.9
Aerospace	6.8	42.98	0	600.12
Biotech	2.9	24.98	0	345.62
Services	3.2	10.5	0	162.46
Communication	2.9	14.2	0	136.51
LQ_6R&D	4	23	0	281.46

S.D.=Standard Deviation

In the other words, there are strong variances within and between the six LQs. While the LQs are, on average, higher than the threshold of being specialized (LQ>1) the high standard deviations show in each category, LQs of some zones are outliers. Further, when an outlier zone has remarkable high LQ in one category, generally has loIr LQ for the other categories (see the distribution chart above). This allows using the highest LQ value to indicate the zone's specialization.

Phase 3-High-tech Firms and Their Different Takes on Walking and Transit Amenities

I tested two sets of models, which both have similar independent variables but different outcomes. The first model compares mono high-tech, diverse and non-high-tech hexagons with respect to transportation infrastructure to assess whether walking and amenities in general attract high-tech industries. The second model then breaks the high-tech industries to its six categories. Including these two models allows me to ansIr my questions that first are transit and walking amenities in general attract high-tech firms, and second are these characters common between all the high-tech subcategories. I estimated the first MNL models using three hexagon's statuses for the outcome: mono-high-tech hexagon (one high-tech category has more than 50% of high-tech employees), multi-high-tech (or diverse) (share of each high-tech category is lesser than 50%), and non-high-tech hexagon (hexagon does not have any high-tech firm). The second model divides the first status of mono high-tech into the six categories of high-tech industry discussed in table 10. To have a better picture of frequency of the statuses of a hexagon, table 14 provides these statistics for both outcomes.

Table 14: Frequency Statistics of the MNLs' Outcomes

Outcome 1	Freq.	Pct.	Outcome 2	Freq.	Pct.
Mono-high-tech	6,477	76.24%	IT	579	6.81%
			Aerospace	113	1.33%
			Bio-pharmaceutical	81	0.95%
			Services	4711	55.45%
			Communications Equipment	459	5.40%
			Education & Knowledge Creation	534	6.29%
Multi-high-tech	698	8.22%	high-tech multi-specialized	698	8.22%
No-high-tech	1321	15.55%	No-High-Tech	1321	15.55%
Total			8496		

Table 15 provides a summary of the variables included in these two models. I also included four measures of transportation infrastructures. I used WalkScore and TransitScore indicating the local accessibility. Developed by Walk Score Inc., these scores measure walkability and transit accessibility for any address point in the U.S. For each address, WalkScore uses walking routes to measure proximity to amenities, which are Iighted differently and discounted as the distance to them increases up to one and a half miles, where they are assumed to be no longer accessible on foot. TransitScore also measures public transit quality. This measure uses the data released by public transit agencies through General Transit Feed Specification (GTFS) including stops and routes for available modes of public transportation (i.e. local, express, and rapid bus routes, commuter rail transit, light rail, streetcar rail, and heavy rail subway-metro systems). Using this data, TransitScore calculates the value of all nearby routes for an address. This value equals to the frequency per Iek multiplied by the mode Iight (heavy/light rail is Iighted 2X, ferry/cable and car/other are 1.5X, and bus is 1X) multiplied by a distance penalty which uses the distance to the nearest stop on a route (Score, 2014). Both WalkScore and TransitScore have been widely used in previous studies analyzing the impacts of walkability and transit accessibility on health outcomes, property value and other economic outcomes such as location preferences and growth of specific industries (Talen and Koschinsky 2013). Further, these scores Ire developed to help public to evaluate the neighborhoods and cities for investment or living(Brewster et al. 2009). I collected these scores for the centroid of each cell.

Table 15: Table Variables

Variable	Description	Source	Mean (s.d.)
Outcomes			
Outcome 1	1= Mono-high-tech, to 2=Multi-high-tech, 3=Nono-high-tech	EBAD (2016)	-
Outcome 2	1 to 6=mono-high-tech in categories 1 to 6 from table 10, 7= multi-high-tech, 8=No High-Tech	EBAD (2016)	-
Independent Variables			
WalkScore	Hexagon's WalkScore	WalkScore Inc. (TBD)	44.57 (24.81)
TransitScore	Hexagon's TransitScore	WalkScore Inc. (TBD)	33.9 (22.14)
Dist_fwy	Network Distance to the nearest freeway ramp (class 0 road segments)	NTADUS and Esri, TomTom (Updated as of 2018)	13.17(12.81)
Dist_Air	Network Distance to the 50 U.S. busiest airports with cargo service	FAA (2017)	39.6 (53.26)
Dist_CBD	Network Distance to the nearest CBD	Hamidi (2015)	15.14 (12.96)
Dist_Uni	Network Distance to number one R&D university in the region	IPEDS (2016)	16.76 (12.33)
Pct_Edu	Percentage of educated workers (with above college degree) living in 1-mile (walking distance) of a hexagon	LEHD RAC (2015)	48.47(6.94)
PctWhite	Percentage of white workers living in 1-mile (walking distance) of a hexagon	LEHD RAC (2015)	74.88 (13.49)
Totemp	Employment size of a hexagon	EBAD (2016)	3089.03 (8036.85)
Agg.	Dummy variable, if the hexagon's zone & the hexagon have similar specialization=1 otherwise 0	Estimated using EBAD (2016)	-
QuanInc	Dummy variable, if the hexagon in a state within the first quantile Corporate Income Tax =1 otherwise 0	Estimated using Upjohn PDIT (2015)	-
QuanPTax	Dummy variable, if the hexagon in a state within the first quantile property tax abatements=1 otherwise 0	Estimated using Upjohn PDIT (2015)	-
QuanR&D	Dummy variable, if the hexagon in a state within the first quantile research and development (R&D) tax credits=1 otherwise 0	Estimated using Upjohn PDIT (2015)	-

EBAD: Esri Business Analyst Dataset
NTADUS: National Transportation Atlas Databases for the United States
FAA: Federal Aviation Administration
IPEDS: Integrated Postsecondary Education Data System
LEHD: Longitudinal Employer-Household Dynamics
RAC: Residence Area Characteristic data

To assess the impact of transportation infrastructure that supports auto-accessibility, I used the network distance to the nearest freeway ramp from the center point of each hexagon. Similar studies that empirically tested the relationship between firm location and transportation facilities found suburb firms in Chicago region and logistics establishments in Los Angeles region placing more importance on proximity to freeway ramps (Kang 2018; Kawamura 2001). Freeway data Ire collected from the National Transportation Atlas Databases for the United States and their connecting ramps Ire identified using Esri and TomTom road network database for the U.S. (Updated as of 2018). Both datasets are in ArcGIS shapefile format and I developed the GIS-based Origin-Destination (OD) matrix to measure the street network distance from a hexagon's center to its nearest freeway ramp.

To assess the impact of air-mobility facilities, I measured the street network distance to the nearest major airport of the region using the same method used for measuring the distance to the nearest freeway ramp. Previous studies on the impact of U.S. major airports on the economic developments included the 25 busiest airports in the nation as the major airports (Appold and Kasarda 2013). This criterion results in some regions with no airport, hence I included the top 50 busiest airports in the nation, which facilitate the business trips made by both domestic and international passengers. Domestic and international business trips are crucial for the high-tech economy since they are export-based industries commonly making businesses with non-local customers (Kasarda 2000) . The U.S. major airports are also improving their facilities for the business-related trips and passengers as the economy further relies on high-tech and knowledge-based firms. Furthermore, since the fast and in time delivery of products is important for high-tech (export-based) industries, I included 46 of the top 50 airports that also provide cargo services.

In addition to measuring the transportation facilities, I also included the control variables that have found to be significant in the business location choice literature. Proximity to CBD is a commonly used factor in similar studies. CBDs could be an important location choice for a firm since are the areas on the top of urban hierarchy and have enhanced accessibility to other parts of the region (Shearmur 2010). I obtained the CBD locations from Hamidi (2015) and computed the street network distance from each hexagon's centroid to the closest CBD. Hamidi (2015) used the spatial statistics and geographically Iighted regression techniques and identified the location of CBDs and employment sub-centers for all metropolitan areas in the U.S. Additionally, university's Research and Development (R&D) expenditure also found to be related with the regional innovation productivity in previous studies. Universities are anchoring the growth of high-tech economy by developing specialized labor force, attracting talents, and fostering knowledge exchange (Acs, Fitzroy, and Smith 1999) . The R&D expenditure of a university not only indicates their poIr in R&D activities but also could indicate their quality of academic services. Using the publicly available Integrated Postsecondary Education Data System (IPEDS), I found the R&D and academic expenditures of universities have almost 0.75 Pearson correlation. This correlation indicates the fact that the universities with the highest R&D expenditure in a region could also be the strongest in educating the students. Hence, to control for this fact in my model, I used the network distance to the university with the highest R&D expenditure in the region. I obtained the universities' R&D expenditure from IPEDS and I used the OD matrix method-similar to other distance-based variables in my model-to measure this variable. In addition to the number 1 R&D universities, I also measured and included a variable indicating the hexagon's access to the educated workforce. I used the percentage of above college-educated employees who live in each cell using the Residence Area

Characteristics (RAC) data from the Longitudinal Employer-Household Dynamics (LEHD) dataset for 2015, which is the most recent released version of this data. Racial diversity is also a key factor that several studies have identified attractive for the knowledge-based firms and creative class (Florida 2002b).Further, many of the high-tech industries outcome their employment and are attracted to skwellful foreign-born work force. I again used the LEHD RAC dataset and included the percentage of white employees who live in each cell. My analysis also controls for the agglomerative forces. Using the total employment size of a hexagon and a dummy variable that indicates whether a hexagon is in its related specialized zone, I controlled for the agglomerative forces that might be critical for the location choice of high-tech industries.

Lastly, my model includes two dummy variable that control for the heterogeneities between different states in which the hexagons locate. These dummy variables indicate whether a hexagon is in a state that is in the first quantile in the nation in terms of both tax incentives and burdens. To compute these measures, I used the Panel Database on Incentives and Taxes dataset provided by Upjohn Institute and included one dummy variable for the corporate income tax (indicates tax burden) an one for property tax abatements (indicates tax incentive). The dummy indicates whether the hexagon state is among the first quantiles of these measures in the nation.

Results

The Location of U.S. High-tech Zones

Overall, I identified 627 high-tech zones in 52 large U.S. regions. These zones are different in terms of location, size, and employment profile.

In terms of location, 390 zones are in an accessible driving distance (10 miles) to CBDs with 62 zones intersecting with CBDs. Moreover, proximity to airports, highways and transit stations are the other general locational attributes of these zones. Accordingly, I observed that 10 major airports are in the center of high-tech zones while nearly 60% of major airports are in a 2.5-mile distance from a high-tech zone (previous studies identified major U.S. airports as the 25 busiest airports which are likely to have an employment node in their 2.5-mile distance (Appold and Kasarda 2013)). Some major airports (e.g. Boston Logan International airport or Mineta San Jose International Airport) are adjacent to CBDs, therefore in such cases, it would be more likely those high-tech zones and airports happen to be adjacent. However, I observed other type of high-tech zones, which are adjacent to the airports that are on the urban fringe (e.g. Dallas Fort Worth, Houston, Los Angeles, Atlanta, etc.). Additionally, while proximity to highways could be a predictable characteristic of high-tech zones, I observed in most of the regions, several high-tech zones have a linear spatial expansion along the major interstate highways. On the other hand, the zones in proximity to CBDs or airports mostly have a clump shape. It might suggest that airports and CBDs could anchor formation of high-tech zones and highways-in addition to CBDs and airports-could affect the spatial form of these zones However, the anchors and indicators of alternative forms of high-tech zones need through assessments, which could be subject of future studies.

High-tech zones have different sizes and residential profiles[3]. While high-tech zones are on average home to nearly 20000 residents or 0.6% of region's population, nearly 7% of the cases have no population. Most of these cases are the suburban industrial districts. The common features of these zones are their location on the urban fringe, expansion along the interstate highways and their high number of high-tech employees and firms. On the other hand, the most populated zones are located in CBDs. For instance, my top 10 biggest zones are the CBDs of major American cities (i.e. New York NY, Boston MA, Houston TX, Chicago IL, Santa Monica and San Francisco CA, Las Vegas NV, Philadelphia PA, Washington D.C., and Pittsburg PA). While on average, almost 43% of zones' residents (older than 25 years old) have the university education, the top 10 educated zones are in Washington D.C., Boston MA, San Jose CA, Austin TX and Denver CO.

In terms of employment profile, on average high-tech zones hold a notable share of employees particularly from the high-tech industries. A high-tech zone, on overage, has nearly 41,165 employees and 2,366 firms. However, nearly 24% of high-tech zones have a below average employment size. For instance, a zone in Manhattan Island of New York has the maximum number of high-tech firms where is home to nearly 7,362 high-tech firms among which 156 are headquarters. Hence, the high-tech zones are highly different driving us to apply a classification method to determine the best arrangement of zones and hexagons high-tech clustering.

I used the Jenks natural break classification in GIS to better visualize the intensity of high-tech activities in hexagons based on the Z-Score. The Jenks natural breaks classification method seeks to reduce the variance within classes and maximize the variance between classes. This is done by minimizing each class's average deviation from the class mean, while maximizing each

[3] I used the American Community Survey 2015 5-year estimate for analysis of residential profile.

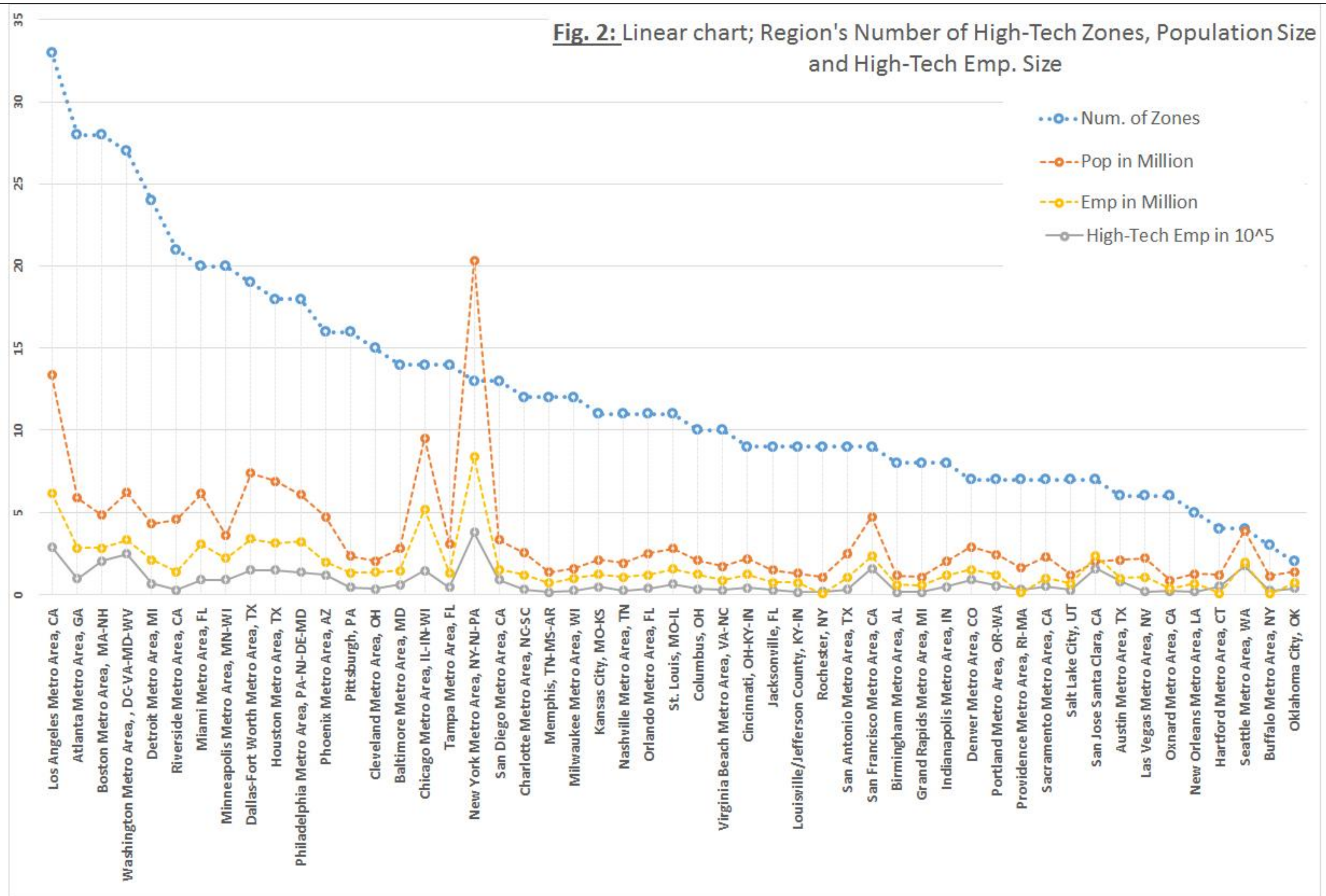
class's deviation from the means of the other groups. Figures 3 illustrates the results of Getis-Ord Gi* analysis in seven regions with the highest intensity of high-tech economy as well as the Dallas Fort-Worth region. Figures 4 shows the previously illustrated eight regions converted into the census geography.

As shown in these maps, the strongest concentration of high-tech activities is in CBDs or downtown areas. CBDs mostly have a higher activity density and thus the hexagons in CBDs contains substantially more number of firms. The strongest cluster of high-tech firms (the cells with the highest Z-Score); expectedly, appears in Manhattan Island in New York MSA. In addition to Manhattan, San Francisco and Chicago metro areas also have the strongest clusters relative to others. These cities play a significant role in the global economy according to the Sassen's identification of Global Cities. Sassen's Global Cities have an ascendance of information technologies, globally active professional services and are strongly involved in the global mobility of capital (Sassen 1991). Following on Sassen (1991) introduction to the concept of Global Cities, other studies also notified Manhattan, Chicago and San Francisco fitting the properties of the globally active cities (Abu-Lughod 1999; Sassen 2013).

In addition to these regions, Charlotte, NC also is in the top tier of high-tech clusters. Charlotte metro area is ranked first with respect to the TechTown Index. Computing Technology Industry Association (CompTIA) (CompTIA 2018) developed this index analyzing metropolitan areas where demand for tech workers is the greatest, controlling for the cost of living, number of open IT positions, and projected job growth over the next five years. Additionally, in the last decade, Charlotte metro area has experienced a double-digit population growth. Charlotte is one of the U.S. key banking centers drawing in a multitude of tech workers. While the median salaries for tech-workers are not as high as those offered on the Ist Coast, the below-average cost of living grant workers more disposable income, making the area an attractive destination for the tech-workers starting their careers.

Figure 4 shows the regions in terms of the number and size of high-tech zones in my sample. Among the 52 U.S. large regions, my hotspot analysis shows only one region- Richmond metro area- does not have any high-tech cluster. Within the rest of the regions, I found 627 high-tech zones in total. These large regions on average have 12 high-tech zones, however, are different in terms of their numbers of high-tech zones. I found that Los Angeles, CA metro area has notably the highest number of zones with 33 zones followed by Atlanta, GA, Washington, DC, Boston, MA, and Detroit, MI metro areas. Oklahoma City metro area has only two high-tech zones, which is the minimum number I observed. My findings also show that generally, the larger regions are likely to have more high-tech zones except few notable outlier regions such as New York-New Jersey and Chicago metro areas. This trend also applies to region's total employment size as well as high-tech employment size. Regions with relatively higher number of zones typically have a fragmented economic and urban spatial structure (Gordon, Richardson, & Wong, 1986). In case of Los Angeles, CA, my results aligned with previous studies that found this region has a highly polycentric spatial structure and the majority of its economic activities are located in the employment sub-centers (Giuliano et al. 2007, 2015; Gordon and Richardson 1996; Gordon, Richardson, and Wong 1986). On the other hand, I found several high-tech regions to have their high-tech firms and employees concentrated in one or few zones including New York, NY metro area and San Francisco, CA and San Jose, CA metro areas in northern California. In these examples, the CBDs are the magnet of high-tech economic activities.

Figure 4: Linear Chart, Number of High-tech Zones, Population and High-tech Employment Size per Region



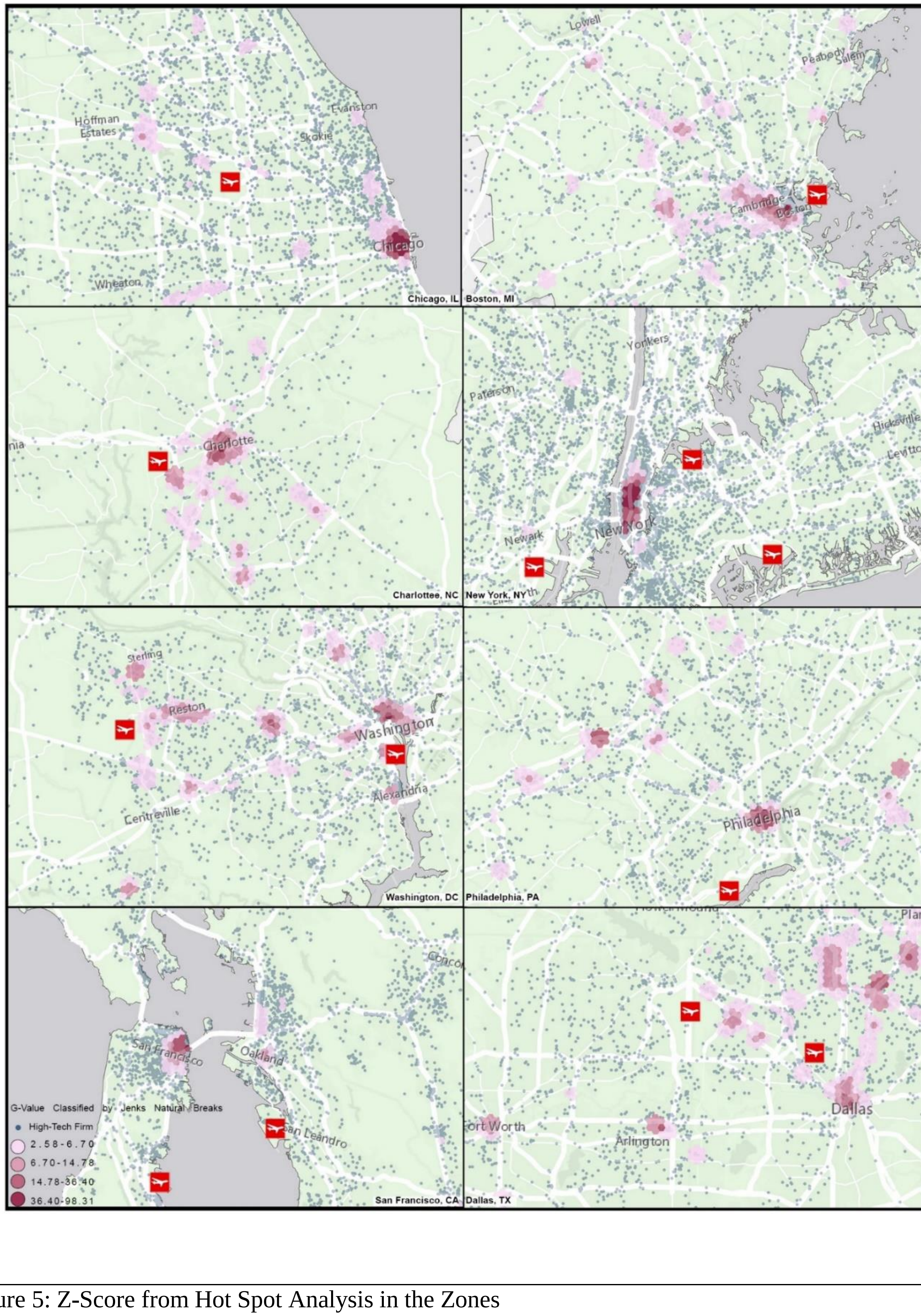


Figure 5: Z-Score from Hot Spot Analysis in the Zones

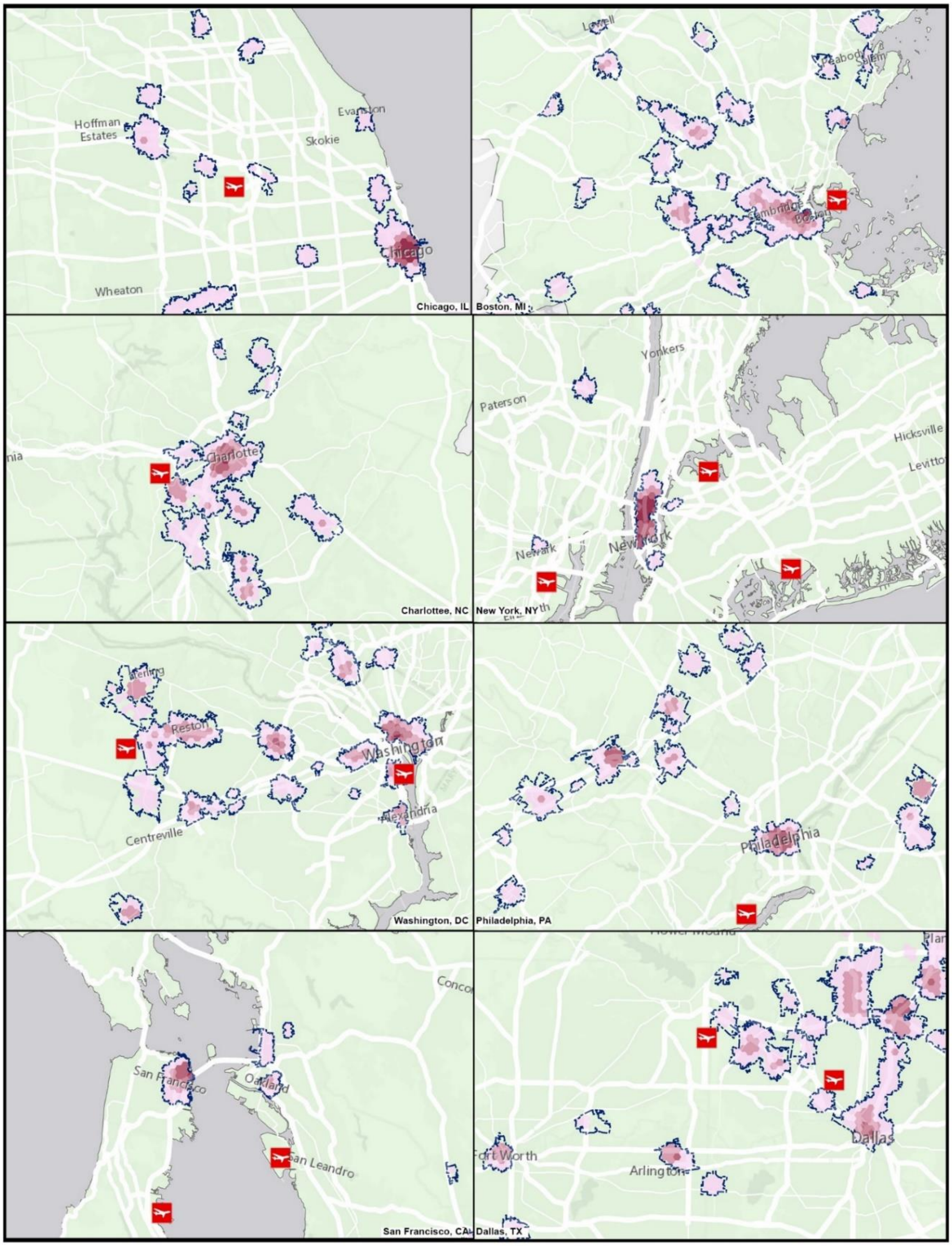


Figure 6: Hexagons Conversion to Zones

The Sectoral Typology of U.S. High-tech Zones

Table 16 shows the distribution of high-tech zones with respect to their specializations, as well as size, employment and residential profiles.

Table 16: Frequency Statistics of High-tech Zones by Specializations in the U.S. large regions.

	Freq.	% from all	% from mono	Avg. Pop.[1]	Avg. Emp.[2]	Edu. Pop[1]	Simp.[3]
Mono Zones	263	42%	100%	16709.6	32685.32	40.12%	0.44
Information Technology	26	4%	10%	9966.96	17394.04	37.02%	0.39
Aerospace	19	3%	7%	7894.737	12337.42	19.94%	0.36
Biopharmaceutical	17	3%	6%	17584.18	42846.12	51.96%	0.42
Services	128	20%	49%	21276.15	40545.8	42.72%	0.47
Communications	24	4%	9%	12782	26176.12	36.80%	0.46
R&D	25	4%	10%	11217.96	25628.16	42.38%	0.43
Diverse Zones	364	58%		21909.04	47292.22	39.38%	0.47
Total	627	100%		19728.10	41165.24	39.67%	0.46

1: Calculated using 2015 American Community Survey 5-Year Estimate
2: Calculated using BAD 2015
3: I used the Simpson (1949) method for measuring diversity. Simpson's Index of Diversity = $= 1 - \sum_k {}^{n}/_{N}{}^{2}$
n=Number of residents of particular category per zone (White, Black, Native American, Asian, Pacific Islander, Hispanic and 'some other race'). N = Total number of residents per zone. The index varies from 0 to 1, with higher values indicating higher diversity (Hamidi and Zandiatashbar 2017).

I found that majority of the zones (58% of all zones) are diverse and nearly 42% of the zones are monopolized by one or few high-tech sectors (LQ>1). Additionally, diverse zones on average have bigger population and employment sizes than mono zones. For instance, on average diverse zones are 1.3 times bigger than mono zones in terms of population and almost 1.5 times bigger in terms of employment size. The other notable feature of high-tech zones is the fact that on average these zones have more employees than residents, which this trend applies to all zone types. For instance, a high-tech zone on average has two times more employees than residents.

Among the six categories of high-tech industries, services hold the majority of zones, almost 49% of the mono zones and 20% of all zones. Therefore, these zones have on average the biggest population size (among mono high-tech zones) and the highest racial diversity of residents. Comparing with the attributes of services specialized high-tech zones, my results also provide notable findings about the biotech zones. Unlike services, which have most of mono-zones, biotech zones have the lowest number of mono-zones (3% of all zones and 6% of the mono-zones); however, have the biggest average employment size. Moreover, these zones also on average have a notably bigger population size and the biggest share of educated residents among all zones. In other words, on average, more than half of a biotech zone's residents have above university education.

While other categories have almost equal distributions, the IT sector slightly has more mono-zones. However, unlike biotech zones, IT zones have the smallest average population size as well as relatively small averages of employment size, share of educated residents, and index of racial diversity. These residential characteristics cope with the locational features of IT zones. I found that majority of IT zones are industrial campuses mostly located on the periphery. In some regions, however, these zones are now in more developed urban areas (e.g. Richardson TX or Belmont CA in Silicon Valley region), However these all IT zones are commonly far from CBDs.

Generally, all CBDs include or are part of high-tech zones. These CBD high-tech zones are generally diverse or specialized in professional services. However, CBDs of Nashvwelle TN and Salt Lake City UT are the zones specialized in communications equipment manufacturing and services. CBDs in Cincinnati OH, Denver CO, and St. Louis MO are also different, home to biotech zones. Other notable different CBD tech zones are in Milwaukee WI, Grand Rapids WY, and Birmingham AL, which are home to R&D tech zones.

Figure 5 Looks at the distribution of different types of high-tech zone in the regions allowing to make comparison between regions. The results from this table indicate that high-tech zones in the U.S. large metro areas are mostly diverse. However, I found 15 metro areas that have more mono-zones than diverse zones including some notable regions such as Seattle metro area, WA, St. Louis metro area, MO-IL, Las Vegas metro area, NV, Chicago metro area, IL-IN-WI, New Orleans metro area, LA, Portland metro area, OR-WA, Detroit metro area, MI and Dallas Fort Worth metro area, TX. Particularly, Detroit metro area, MI, and Dallas-Fort Worth, TX metro areas are among the top 10 regions in terms of the number of high-tech zones while the majority of their zones are monopolized by a specialized high-tech industry. I found that Los Angeles, CA metro area has the highest number of zones including 33 zones. While nearly 80% of the high-tech zones in Los Angeles, CA metro area are diverse, the other 20% are specialized in services, R&D, and IT. (Figure 6 shows the spatial distribution of these zones).

My findings also show that the high-tech economy in the U.S. highly depends on professional services. This category includes the firms primarily designed to support other businesses such as consulting, legal services, facilities support services, computer services, engineering and architectural services, and placement services (Delgado et al., 2015). There is no manufacturing and production process among these industrial sectors while their growth highly depends on their access to talents (Delgado, Porter, & Stern, 2010). However, the large manufacturing high-tech industries like aerospace have notably fewer mono-high-tech zones in the U.S. large regions. More than 85% of employment in this industrial sector is currently located in six metropolitan regions including Seattle, WA, Los Angeles, CA, Dallas-Fort Worth, TX, Hartford, CT, Boston, MA and Cincinnati, OH (Niosi & Zhegu, 2010). Niosi and Zhegu (2010) explain that the growth of aircraft industry could follow the concept of anchor tenant. The anchor tenant is often a large high-tech firm or a research university or public laboratory that produces knowledge externalities and can lead to spinning off new companies and attracting other ones. These dynamics could help to explain the growth of aerospace high-tech zones in these six regions since these dynamics are industry specific particularly specific to the aircraft industry. The remaining types of mono-zones are not widely different in terms of sizes; however, each could be study area for the future in-depth study of the locational behavior of these industries.

Figure 7: High-tech Zone Typology per Region

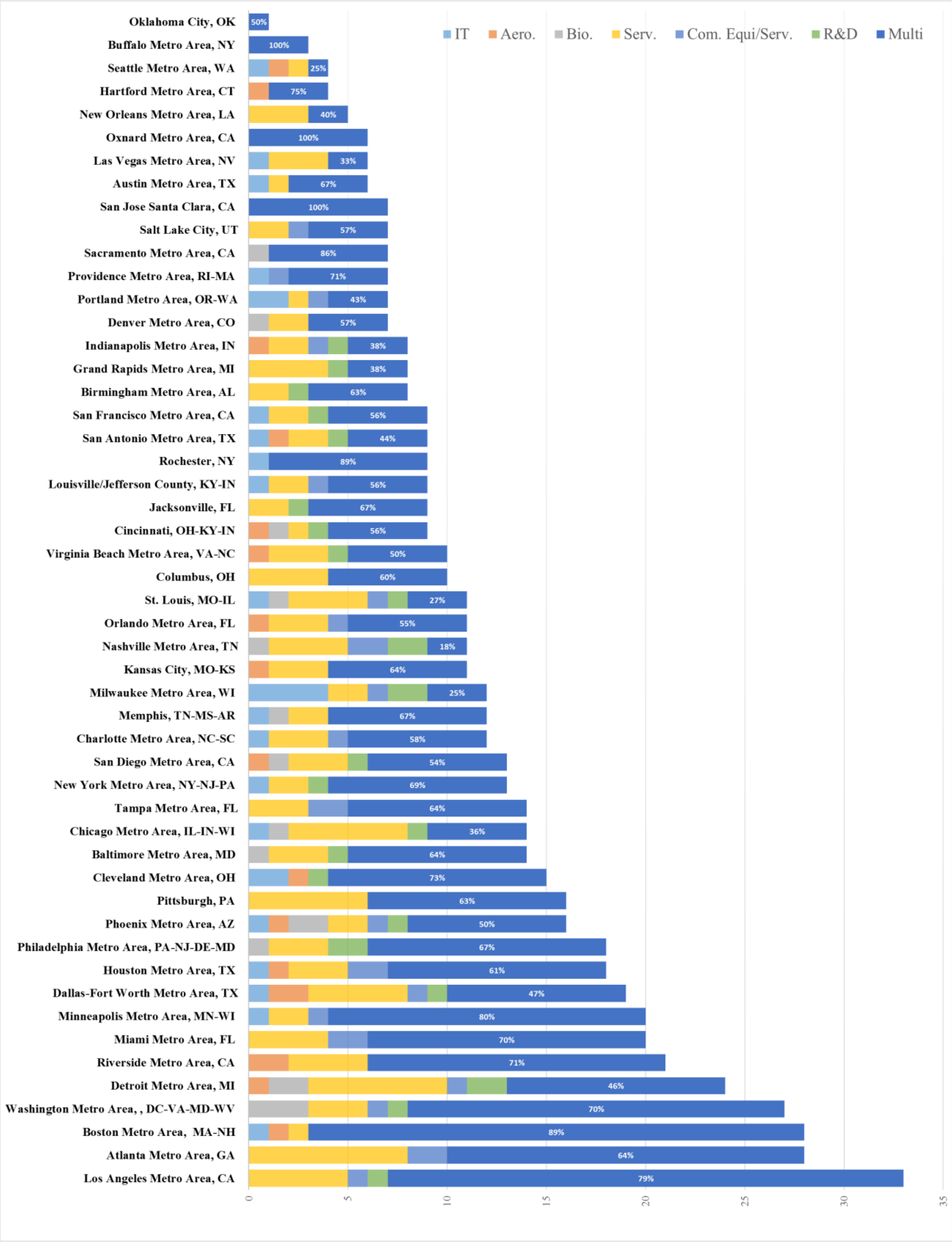
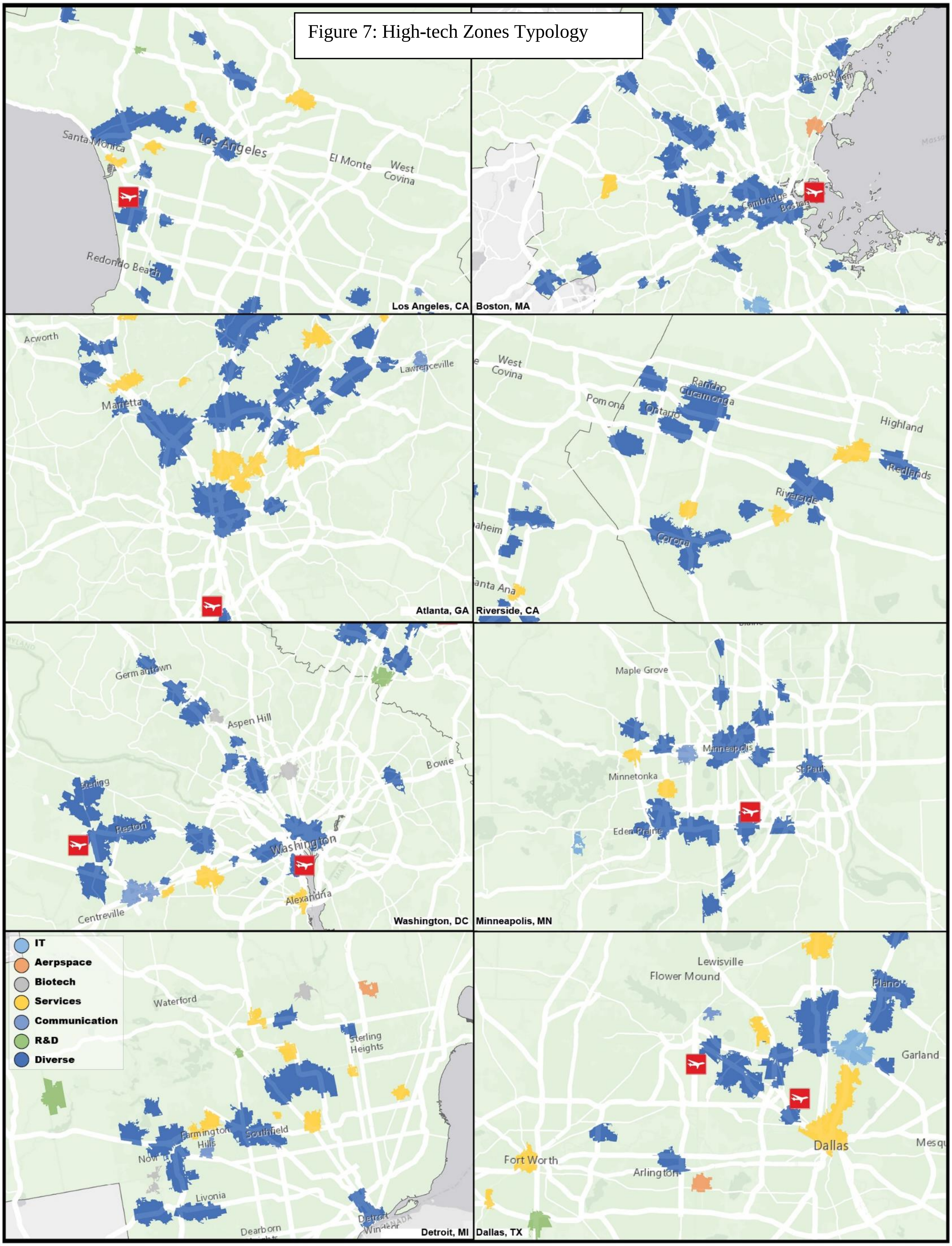


Figure 7: High-tech Zones Typology



High-Tech Firms and Their Different Takes on Transit and Walking Amenities

I used Stata 15 to develop the two series of models with the results presented in tables 16, 17 and 18. The first models compare the high-tech hexagons with non-high-tech hexagons, hence includes three outcomes for a hexagon. The second set evaluates the difference between different high-tech categories and thus includes all the six categories discussed in table 10. Due to the multicollinearity issue between TransitScore and WalkScore, they are inserted in the models separately. However, the difference in results stemming from this separation is not significant.

The first set of models includes three outcomes for the hexagons including mono-high-tech, multi high-tech and non-high-tech. To identify whether walkability, transit accessibility, auto-accessibility and air mobility facilities attract the high-tech firms, the base outcome is the third status, when the cell does not include any high-tech firm. According to the likelihood ratio test for the first models the less restrictive models (presented in table 16) fit the data significantly (at 99% level of confidence) more than the more restrictive models.

Table 16: Results from the first MNL models, comparison between high-tech and non-high-tech hexagons

VARIABLES	Mono-High-tech		Multi-High-tech	
WalkScore	0.02***		0.01***	
	(0.002)		(0.003)	
TrnsitScore		0.02***		0.006*
		(0.003)		(0.004)
Dist_fwy	-0.01***	-0.01***	-0.01*	-0.009*
	(0.004)	(0.004)	(0.005)	(0.005)
Dist_Air	-0.002***	-0.0007	-0.009***	-0.008***
	(0.0008)	(0.0009)	(0.001)	(0.001)
Dist_CBD	-0.008**	-0.006*	0.0003	0.0002
	(0.004)	(0.004)	(0.005)	(0.005)
Dist_Uni	-0.008*	-0.008*	0.01**	0.01*
	(0.004)	(0.004)	(0.005)	(0.005)
Pct_Edu	0.02**	0.02**	0.02**	0.02**
	(0.008)	(0.008)	(0.009)	(0.009)
Pct_White	0.01***	0.009***	0.01***	0.01***
	(0.004)	(0.003)	(0.005)	(0.004)
Totemp	0.001***	0.001***	0.001***	0.001***
	(6.42e-05)	(6.39e-05)	(6.43e-05)	(6.40e-05)
Agg.	20.4	21.4	18.4	19.4
	(394.9)	(650.9)	(394.9)	(650.9)
QuanInc	0.06	-0.05	0.3**	0.334**
	(0.1)	(0.1)	(0.1)	(0.1)
QuanPTax	0.8***	0.8***	0.2	0.2
	(0.1)	(0.1)	(0.2)	(0.2)
Constant	-3.3***	-3.2***	-4.9***	-4.5***
	(0.4)	(0.4)	(0.5)	(0.5)
Observations	8,496			

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

LR chi2 = 5027.70
Prob > chi2 = 0.0000
Pseudo R2 = 0.42

LR chi2 = 4972.87
Prob > chi2 = 0.0000
Pseudo R2 = 0.42

The results of first MNL models confirm that walkability, transit accessibility, proximity to freeway ramps, and major regional airport are critical for high-tech firms. However, proximity to freeway ramps appears to be more significant for the mono- high-tech hexagons, along with proximity to CBD. Proximity to the top R&D University in the region is also an important factor, particularly for the mono-high-tech hexagons; However, the multi-high-tech hexagons are significantly further away from the R&D universities.

In general, the high-tech firms are attracted to the cells where a higher percentage of educated employees live. The cells with a higher percentage of white employees are also more likely to have high-tech firms and so are the indicators of agglomerative forces. Lastly, among the state-level indicators, the first quantile states in terms of property tax abatements are significantly more likely to host the mono- high-tech cells, while this factor is not significant for the multi-high-tech cells. On the other hand, the states that are in the first quantile in terms of corporate income tax are more likely to host the multi-high-tech hexagons, while this factor is not significant for the mono-high-tech hexagons.

The first models show that high-tech industries demand transportation facilities of all major modes. While, this is in line with previous studies that empirically tested the location choice of high-tech industries in general, this could also be due to a gap in the literature. Previous studies combined high-tech industries in one category, whereas their subcategories could have different location behaviors. Some subcategories might prefer auto accessibility, while others transit networks, but together they will be attracted to all four major modes of transport. Hence, researchers by using this approach do not allow understanding and unleashing the differences between high-tech sub-sectors. Furthermore, in cease of proximity to university or CBD, there is a significant contrast between mono-high-tech and multi-high-tech hexagons. This also might be because some high-tech industries might favor proximity to CBD or universities; However, this is not generalizable to all high-tech industries. In sum, the first models to some extend could confirm my hypothesis that high-tech industries do not have similar location behavior, which requires a model that controls for these differences.

Herein the second models address this gap in the literature and evaluate the differences between the six high-tech categories from table 10. The outcome variable indicates eight statuses by including six types of mono-high-tech (refer to the six high-tech categories from table 10), multi-high-tech (once a high-tech category does not reach more than 50% of total high-tech employees) and the non-high-tech hexagon. Again, due to the multicollinearity issue between TransitScore and WalkScore, they are inserted in the models separately. However, this separation does not lead to different results. Table H presents the results of these MNL models. In this set of models, I aim to address the differences between the categories. If the six categories have equal share in a cell, each will have almost 16% of high-tech employees, which is a rare scenario. On the other hand, my multi-high-tech cells have different shares of high-tech employees; the averages of the shares of the six categories vary between 13% and 30% and a high-tech category rarely has 30% share in high-tech employees. Hence, if a high-tech category has a more than 50% share of the high-tech employees, it will be a mono-high-tech specialized in that category. This status is a big difference between two attributes of a cell, and this analysis is interested in assessing the factors that could increase the probability of a cell to transform from a diverse cell to a monopolized cell. Therefore, and for the ease of interpretation, in the second models I select multi-high-tech as the reference category.

The results from the second models are presented in tables 5 and 6. Similar to the first models, the likelihood ratio test shows that the second models (the less restrictive models) also fit the data significantly (at 99% level of confidence) more than the more restrictive models. The interpretations from the MNL models could only be made in comparison with the reference outcome (multi-high-tech). Furthermore, the coefficients from MNL models are not interpretable with respect to change of one unit in a variable; hence, I also estimated and included the marginal effects for the six high-tech categories. In so doing, I can interpret the location behavior of high-tech specializations independent of the reference outcome and in response to one unit change of the explanatory variables of interest. Table 18 provides the estimated marginal effects.

Overall, the results of the second models reveal different location preferences between the six high-tech specializations with respect to walkability, transit accessibility, and access to freeways and major airports, as well as other locational determinants. Particularly the findings about walkability and transit accessibility are strongly different, needing attention for the specializations individually.

According to my results, walkability is only significant for professional services. The P-values for communication devices and R&D are both 0.101, which is nearly significant. On the contrary, the specialized cells in IT and aerospace are significantly less walkable than multi-high-tech cells. According to the marginal effect estimations, If WalkScore increases by one unit, the hexagon is 0.16% less likely to be specialized in IT and 0.03% less likely to be specialized in aerospace. However, in the same situation, it is 0.34% more likely to be specialized in services. Meanwhile, the MNL results enable comparison with the reference outcome, and per this comparison, the mono-high-tech cells specialized in communication devices and R&D specializations are almost significantly more walkable; according to the marginal effects, walkability is only important for the professional services.

Transit accessibly has almost similar pattern. Again, professional services, communication devices and R&D specializations are significantly more transit friendly than multi-high-tech cells. Further, the aerospace industrial cells are significantly less transit accessible than diverse high-tech industrial cells. In other words, if TransitScore increases by one unit, the likelihood of a cell to be IT specialized decreases by 0.14%, and the likelihood of being aerospace specialized decreases by 0.02%. On other hand, the same situation increases the likelihood of a cell being only service-oriented high-tech by almost 0.4%. In sum, the preferences for Walkability and transit accessibility between different specializations are almost similar.

Table 17: MNL models results, evaluating location behavior of different high tech industrial categories

VARIABLES	IT Instruments		Aerospace		Bio-pharmaceutical		Services		Communications Devices		R&D		Non-high tech	
WalkScore	-0.02***		-0.02***		-0.002		0.01***		0.005		0.004		-0.01***	
	(0.002)		(0.005)		(0.006)		(0.002)		(0.003)		(0.003)		(0.003)	
TransitScore		-0.01		-0.01*		-0.01		0.02***		0.008**		0.008**		-0.006*
		(0.004)		(0.006)		(0.007)		(0.003)		(0.004)		(0.004)		(0.004)
Dist_fwy	0.002	0.001	-0.01	-0.02	-0.04**	-0.03***	-0.005	-0.002	0.007	0.008	-0.008	-0.007	0.009*	0.009*
	(0.005)	(0.005)	(0.008)	(0.009)	(0.01)	(0.01)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Dist_Air	0.005***	0.005***	0.008***	0.008***	0.01***	0.01***	0.006***	0.007***	0.007***	0.008***	0.01***	0.01***	0.009***	0.008***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)
Dist_CBD	-0.01**	-0.009	-0.007	-0.006	-0.009	-0.01	-0.01***	-0.008**	0.002	0.003	-0.005	-0.003	-5.36e-05	-3.45e-05
	(0.006)	(0.001)	(0.009)	(0.009)	(0.01)	(0.01)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Dist_Uni	-0.01***	-0.01**	0.004	0.004	-0.01	-0.01	-0.02***	-0.02***	-0.02***	-0.02***	-0.03***	-0.03***	-0.01**	-0.01**
	(0.005)	(0.005)	(0.007)	(0.007)	(0.01)	(0.01)	(0.003)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Pct_Edu	0.01	0.01	-0.09***	-0.08***	-0.02	-0.03	-0.003	-0.0002	-0.01	-0.01	-0.005	-0.003	-0.02**	-0.02**
	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.007)	(0.007)	(0.01)	(0.01)	(0.01)	(0.01)	(0.009)	(0.009)
Pct_White	-0.01***	-0.02***	-0.009	-0.008	0.002	0.003	-1.67e-05	0.0007	-0.01***	-0.01***	-0.01**	-0.01**	-0.01***	-0.01***
	(0.005)	(0.005)	(0.008)	(0.008)	(0.01)	(0.01)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Totemp	-1.03e-05	-2.13e-05*	3.76e-06	4.58e-07	2.90e-06	5.47e-06	-1.58e-05***	-1.74e-05***	-7.75e-05***	-8.20e-05***	-9.33e-06	-1.14e-05*	-0.001***	-0.001***
	(8.98e-06)	(1.15e-05)	(1.18e-05)	(1.37e-05)	(7.06e-06)	(7.20e-06)	(4.39e-06)	(4.50e-06)	(2.03e-05)	(2.04e-05)	(6.62e-06)	(6.93e-06)	(6.43e-05)	(6.40e-05)
Agg.	2.3***	2.4***	2.4***	2.5***	2.7***	2.7***	2.1***	2.1***	1.6***	1.6***	1***	1.01***	-19.4	-19.4
	(0.1)	(0.1)	(0.3)	(0.3)	(0.3)	(0.3)	(0.09)	(0.09)	(0.1)	(0.1)	(0.1)	(0.1)	(649.9)	(669.6)
QuanInc	0.2	0.3*	0.7***	0.8***	0.5*	0.6**	-0.4***	-0.5***	-0.5***	-0.5***	-0.1	-0.2	-0.3**	-0.3**
	(0.1)	(0.1)	(0.2)	(0.2)	(0.3)	(0.3)	(0.1)	(0.1)	(0.2)	(0.2)	(0.1)	(0.2)	(0.1)	(0.1)
QuanPTax	0.4*	0.3	-0.07	-0.1	0.7**	0.8**	0.7***	0.7***	0.4**	0.4**	0.1	0.08	-0.2	-0.3
	(0.2)	(0.2)	(0.4)	(0.4)	(0.4)	(0.4)	(0.1)	(0.1)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)	(0.2)
Constant	-0.3	-1	1.8*	1.5	-2.7**	-2.1*	0.6	0.4	0.4	0.2	0.5	0.3	5***	4.6***
	(0.6)	(0.6)	(0.9)	(1.005)	(1.2)	(1.2)	(0.4)	(0.5)	(0.6)	(0.6)	(0.6)	(0.6)	(0.5)	(0.5)
Observations							8,496							

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

LR chi2(84) = 5789.84
Prob > chi2 = 0.0000
Pseudo R2 = 0.24

LR chi2(84) = 5610.12
Prob > chi2 = 0.0000
Pseudo R2 = 0.23

Table 18: Marginal effect estimates, evaluating location behavior of different high tech industrial categories

	IT Instruments		Aerospace		Bio-pharmaceutical		Services		Communications Devices		R&D		multi-high tech	
VARIABLES							dy/dx							
WalkScore	-0.002***		-0.0003***		-0.0001**		0.003***		-0.0003*		-0.0003**		-0.0008***	
	(0.0001)		(0.00006)		(5.00e-05)		(0.0003)		(0.0002)		(0.0002)		(0.0002)	
TransitScore		-0.001***		-0.0003***		-0.0002***		0.0032***		-0.0002		-0.0003		-0.001***
		(0.0002)		(0.0007)		(6.00e-05)		(0.0004)		(0.0002)		(0.0002)		(0.0002)
Dist_fwy	0.0003	0.0002	-0.0001	-0.0001	-0.0003**	-0.0003***	-0.007	-0.0003	0.0007***	0.0007***	-0.0003	-0.0004	0.0003	0.0002
	(0.0002)	(0.0002)	(0.0009)	(0.0008)	(0.0001)	(0.0001)	(0.0005)	(0.0005)	(0.0002)	(0.0002)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Dist_Air	-8.13e-05	-0.0001	3.00e-05	1.78e-05	4.94e-05**	3.11e-05	0.00001	0.0003**	0.0001**	0.0001	0.0003***	0.0003***	-0.0005***	-0.0006***
	(7e-05)	(7e-06)	(0.00002)	(2e-05)	(2.00e-05)	(2.00e-05)	(0.0001)	(0.0001)	(0.0001)	(0.0006)	(0.00006)	(0.00007)	(0.0001)	(0.0001)
Dist_CBD	-0.0003**	-0.0002	9.00e-06	-1.33e-06	-7.18e-06	-0.0001	-0.001**	-0.001**	0.001**	0.001**	0.0002	0.0003	0.0007**	0.0005**
	(0.0003)	(0.0003)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0005)	(0.0005)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Dist_Uni	0.0003	0.0003	0.0003**	0.0002***	3.52e-05	1.46e-05	-0.001**	-0.001**	-0.0001	-0.0001	-0.00008**	-0.00008**	0.002**	0.001**
	(0.0002)	(0.0002)	(0.0001)	(0.0001)	(0.00009)	(0.0001)	(0.0005)	(0.0005)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Pct_Edu	0.0001**	0.001**	-0.001***	-0.001***	-0.0002	-0.0003	0.0001	0.0009	-0.001	-0.001	-0.0001	-0.0001	0.0003	0.0001
	(0.0005)	(0.0003)	(0.0001)	(0.0002)	(0.0002)	(0.0002)	(0.0001)	(0.001)	(0.001)	(0.001)	(0.0006)	(0.0006)	(0.0006)	(0.0006)
Pct_White	-0.0008***	-0.0009***	-7.16e-05	-0.0001	4.25e-05	4.83e-05	0.002***	0.002***	-0.001***	-0.001***	-0.0007**	-0.0007**	0.0003	0.0002
	(0.0002)	(0.0002)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0005)	(0.0005)	(0.0002)	(0.0002)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Totemp	4.69e-07	-1.17e-07	2.39e-07*	2.31e-07	1.89e-07***	2.22e-07***	1.01e-06	1.48e06	-4.05e-06***	-4.17e-06***	6.57e-07	6.69e-07	1.52e-06***	1.68e-06***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Agg.*	0.04***	0.04***	0.007**	0.007**	0.008**	0.008**	0.3***	0.2***	-0.01	-0.01	-0.6***	-0.6***	-0.2***	-0.2***
	(0.006)	(0.006)	(0.002)	(0.0024)	(0.002)	(0.002)	(0.01)	(0.01)	(0.01)	(0.01)	(0.008)	(0.008)	(0.01)	(0.01)
QuanInc*	0.04***	0.05***	0.01***	0.02***	0.009**	0.01***	-0.08***	-0.1***	-0.01*	-0.01	0.01	0.01	0.02***	0.03***
	(0.009)	(0.008)	(0.004)	(0.005)	(0.004)	(0.004)	(0.02)	(0.02)	(0.01)	(0.01)	(0.009)	(0.009)	(0.009)	(0.01)
QuanPTax*	-0.01	-0.02*	-0.006**	-0.007**	0.002	0.0022	0.09***	0.1***	-0.01	-0.01	-0.03***	-0.03***	-0.04***	-0.04***
	(0.009)	(0.009)	(0.003)	(0.003)	(0.004)	(0.0036)	(0.02)	(0.02)	(0.01)	(0.01)	(0.009)	(0.008)	(0.008)	(0.008)
Observations							8,496							

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

(*) dy/dx is for discrete change of dummy from 0 to 1

With respect to easy access to freeways, among all specializations, only the biopharmaceutical industries are significantly different from multi-high-tech hexagons. This category appears to be closer to freeway ramps in comparison with multi-high-tech hexagons. In other words, and using the results from table 18, all high-tech industries are likely to locate in proximity to a freeway ramp, although some categories (e.g. biopharmaceutical) are more likely.

Quite the contrary, proximity to the major airport of a region is not a common locational character between all hexagons. Multi-high-tech hexagons are significantly distinct from all others in placing more importance on proximity to major airports. According to the marginal effects, except for the IT and multi-high-tech cells, proximity to a major airport does not attract any other mono-high-tech cells, however this character is not significant for IT as Well. In other words, being one mile closer to a major airport increases the likelihood that a cell will be multi-high-tech by 0.05%, while being one mile further from the major airport increases the likelihood of a cell to be specialized in R&D activities by 0.03%.

My models also include non-transportation factors that have been theorized to play role in the location decision of high-tech firms. Proximity to CBD can provide access to customer market and hence, theoretically, play a significant role in business location behavior (Doloreux and Shearmur 2012). Except the communication devices industrial hexagons, all other types of mono-high-tech hexagons are closer to CBD when comparing with the multi-high-tech hexagons. However, this difference appears to be highly significant only for professional services. Additionally, the marginal effects also generally follow the same pattern. Among all six high-tech categories, proximity to CBD appears to be significant only for the services industries. It is 0.13% more likely that a cell is majorly occupied by professional services industries once the distance to CBD decreases by one mile.

The result of second MNLs also explains why that the multi-high-tech hexagons do not locate in proximity to the major R&D university of their regions. In general, all of the mono-high-tech hexagons (except the aerospace specialized hexagons) locate closer than multi-high-tech hexagons to the major R&D University in their regions. Particularly with respect to the marginal effects of this variable, proximity to the highest R&D University in the region significantly attracts the firms in professional services and R&D industries. For instance, being one mile closer to the R&D University increases the chance that the hexagon is specialized in services by 0.13%, and in R&D by 0.08%. On the other hand, it is 0.16% that a hexagon is multi-high-tech once distancing one mile further from the R&D University.

The IT cells are the only type of hexagons that have a significantly higher share of educated employed residents in their cells; However, this situation is inverse for the aerospace hexagons. Overall, aerospace hexagons are significantly different hexagon type when comparing with the multi-high-tech hexagon in terms of share of educated residents. However, the percentage of white workers living in hexagons are significantly in the hexagons of IT, communication devices and R&D types particularly more than multi-high-tech hexagons.

In general, the multi-high-tech hexagons have bigger employment size than other types of hexagons, and are more attracted to their zones . The aerospace and bio-pharmaceutical hexagons are significantly more likely to be in the first quantile states in terms of corporate income tax as compared to the multi-high-tech hexagons. Furthermore, the bio-pharmaceutical and professional services hexagons are significantly more likely than multi-high-tech hexagons to be in the first quantile states in terms of offered property tax abatement in 2015.

Discussion and Conclusion

This study is a step moving forward in the literature of economic geography. While the current economic era has been increasingly inclining towards the high-tech businesses, there has yet to be an attempt to detect the location of high-tech zones in the U.S. at the disaggregated level. This study is one of the first efforts that detected the high-tech zones at the most disaggregated level and identified their sectoral types in the U.S. large regions using a systematic approach.

I identified 627 high-tech zones in seven sectoral types in the U.S. large regions most of which are diverse or specialized in professional services. High tech zones in the large U.S. regions are on average home to more employees than residents hence are the major job destinations in the regions. These zones locate differently in their regions; for instance, CBDs generally are home to diverse or specialized zones in services industries and IT high-tech zones are mostly on the urban fringe. On the other hand, regions are different in terms of the number of zones that they have. Some regions have fragmented high-tech zones spreading across the regions (e.g. Los Angeles CA, Boston MA, Washington D.C., Dallas Fort Worth TX) while others have majority of their high-tech industries concentrated in few zones (e.g. New York NY, Denver CO, San Francisco and San Jose CA).

High-tech industries are increasing their share of national employment making the high-tech zones the notable job destinations in the U.S. regions. This results in increased demands for the daily commutes of the regional workers, while also can exacerbate social and labor division and the displacement of the local residents (Cervero 1989; Scott and Storper 2003) . Therefore, my findings on the high-tech zones could bring a significant contribution to the policy development arena. Accordingly, location and size of this job zones as well as their region’s type in terms of the fragmentation level of high-tech zones could guide on how and where the mobility systems should be expanded. Number of high-tech job zones in a region also helps policy development with economic growth and equity purposes. For instance, the region's economic growth policies should consider that clustering of high-tech industries in fewer zones runs a higher risk of suburban poverty and spatial polarization. The extreme concentration of high-tech activities in one or few zones could potentially increase the risk of labor division, spatial mismatch, and segregation (Cervero 1989; Scott and Storper 2003). The high-tech booming regions with the concentrated zones need to foster the entrepreneurial ecosystems and support the high-tech spinoffs into the new designated zones. On the other hand, more zones in a fragmented region also could lead to increased traffic congestion if the zones are not a work and live urban area.

With respect to the growing interest in developing work, live and play urban areas, my results on the employment and residential profiles of the high-tech zones open venues for future studies by suggesting interesting cases. For instance, while the employment size of a high-tech zone is on average two times bigger than its population size, my results show that the biotech zones (while very few in the U.S. large regions) on average are bigger in terms of population who are on average mostly educated residents. These could suggest that, biotech zones could possibly hold a better balance of work and live relative to other zones. While the scope of this research was only identifying the location and sectoral type of high-tech zones, researchers interested to unleash the formation of work, play and live areas could look at the development types of the remarkable biotech zones where educated workers live and work.

While different economic anchors could result in formation of a high-tech zone, my results support findings from Appold & Kasarda (2013) that show the U.S. major airports could anchor employment clusters within their 2.5 mile proximity. With respect to high-tech zones, my findings show nearly 80% of U.S. major airports are in less than a 5-mile distance from a high-tech zone and that 10 major airports are home of the high-tech zones. Most of these zones have diverse or professional services specializations. Such results refocus a question about the nature of major airports within metropolitan regions supporting high-tech zones and economic growth. With the rise of global cities, there is growing interest among researchers to uncover the attributes of Airport City Phenomenon (e.g. Appold, 2015; Appold & Kasarda, 2013; D'Alfonso, Bracaglia, & Wan, 2017; Kasarda, 2000; Witlox, Derudder, & Devriendt, 2007) and my results suggest that this role is worth more research in the high-tech economy. Researchers could select interesting cases from my findings for future research on the formation of airport cities.

The rise of high-tech economy has been forming the both academic and policy development efforts. While it has been projected that the high-tech economy will be growing during the next two decades, there has been a little attention paid to the local high-tech zones. This study is among the first attempts, which unleashed the location and sectoral types of high-tech zones in the U.S. large regions. This attempt brings a significant contribution to both local policy developments and future scholarly works. My results provide ample cases for analysis of work live and play urban areas, airport-based economic zones, and location behavior of high-tech firms. On the other hand, my results also help policy makers to accommodate for job destinations in their regional mobility planning efforts as well as smart growth management policies that prevent suburban poverty and spatial polarization in the regions with clustered high-tech zones and congestion in the fragmented regions.

Furthermore, little attention has been paid to the high-tech economy's relationship to transportation infrastructure despite long-standing research exploring the relationship between transportation infrastructure, land use, and economic development (Mohammad et al. 2013). Rather, the dominant framing of the knowledge economy in terms of agglomeration economies and creative class policies has tended to shape knowledge economy development policies in terms of location incentives and placemaking initiatives in order to promote clustering. While these strategies include walkability and access to transit, these preferences and strategies likely only apply to a subset of high-tech industries. A large number of high-tech firms may prefer and therefore continue to produce more auto-centric developments on the urban fringe (Maggioni, 2002). As policymakers continue to pursue knowledge-based economic development strategies and empower their regional high-tech industries, it is important to identify transportation preferences in order to understand the role these industries play in developing new spatial forms and their implications for sustainability outcomes.

My empirical results support theoretical work indicating that different types of high-tech firms seek different transportation infrastructures. While in general walkability, transit accessibility, road accessibility, and proximity to major airports play critical role in location decisions of high-tech firms, my results show that these tendencies vary between different high-tech industries. For instance, I found that the mono-high-tech hexagons of professional business services have significantly higher marginal effects for WalkScore and TransitScore, while being significantly more walkable and transit accessible compared to multi-high-tech hexagons. Business service industries include computer/system services and engineering and architecture firms, which are primarily designed to provide services to other businesses, facilities or unrelated companies (Maggioni, 2002). Consequently, they are highly reliant on a specialized workforce to deliver high-order services and concentrate in walkable and transit accessible CBDs in order to cover a wider market area (Zandiatashbar and Hamidi, 2018). Furthermore, they provide services or immaterial commodities, which unlike traditional manufacturers, do not need or seek cheaper, larger or more peripheral land areas for their manufacturing facilities (Maggioni, 2002). These firms also draw upon the externalities of frequent face-to-face encounters and tacit knowledge exchange that stem from their proximity in dense and walkable CBDs. For these reasons, my results verify that these types of high-tech industries prefer proximity to CBD as well as top R&D universities of their regions.

On the other hand, my results also confirm that not all of high-tech industries prioritize walkability, transit accessibly or proximity to CBDs. For instance, IT, aerospace and pharmaceutical sectors have significantly lower WalkScore and TransitScore, while aerospace and pharmaceutical sectors significantly place more priority on proximity to freeway access. Unlike the business services, IT employees mostly exchange codified knowledge. Recent studies indicate that online digital interactions could be a substitute for face-to-face encounters when exchanging codified knowledge (Audirac, 2002; Relph, 1976). Moreover, IT, aerospace, and pharmaceutical sectors firms manufacture, process and distribute goods, which need production facilities usually on peripheries (Maggioni 2002). In addition, IT's involvement in e-commerce deepens their demand for air mobility, which, according to my results, is why IT sectors are generally closer to the major airports of their region (Kasarda, 2000). In addition to IT sectors, my results show that the busiest commercial airports in the U.S. may be emerging as central transport nodes in large metropolitan areas, much as ports and rail terminals Ire in the past. In my analysis, the multi-high-tech hexagons are significantly attracted to the major airports in their regions. Airports are functioning beyond facilitating leisure trips nowadays and their business travels and goods shipment increased rapidly over the past several decades (Appold and Kasarda 2013). Hence, major airports are anchoring employment centers and providing a spatial focus for unrelated and diverse firms. My results are in line with pervious analysis of U.S. major airports, which found concentration of employment within 2.5 miles of these airports to be substantial (Appold and Kasarda 2013). Such analyses refocus a question about the nature of major airports within large metropolitan regions in supporting multiple employment nodes.

These findings suggest that more critical attention is required for understanding the relationship between knowledge-based firms and their preferences for transportation infrastructure. The dominant narrative regarding the spatiality of knowledge-based clusters suggests that these industries prefer dense, walkable, mixed use, transit accessible urban environments. My research supports this theory, however, only partially. My findings suggest that large numbers of high-tech firms are still attracted to peripheral, auto-centric spaces, which is at odds with transportation policies supporting smart growth management. My results also support the concerns about unmanageable growth and congestion as the result of high-tech economic growth. Despite the long-standing debates regarding economic developments and growth management, my findings demonstrate that many of these high-tech zones may be problematic in terms of their environmental impacts. In light of these findings, policymakers may need to attend to balanced growth strategies to not only succeed in growing their knowledge economy, but also to ensure they address the negative externalities of a high-tech economy.

Chapter 5: Conclusion and Policy Implications

Overall Conclusion

This dissertation covers multiple empirical analyses in order to unleash the dynamics between of transit and walking amenities and economic development in the 21st Century. In this new economy, mass-production (Fordism) being driven by the monopolistic manufacturing firms is substituted with creativity, speed, and flexibility in production which requires high-tech based sectors and innovation (K. N. Credit 2018). Hence, this dissertation includes the pioneer research studies in the literature that explore the impact of walking and transit amenities on the location and growth of U.S. Specialized high-tech zones, knowledge-based and creative industries, and innovation productivity of small businesses.

In the first essay, I developed a Structural Equation Modeling to capture the direct, indirect and total effects, through which I found that transit service quality increases the innovation productivity through attracting KIBS. Walkability also attracts KIBS through attracting creative industries. These findings from the first essay call for more innovation friendly place-based policies and plans. While federal organizations (like SBA) support innovation production, localities also can develop the complementary policies that enhance the proximity of STEM small firms or startups (like SBIR firms) to KIBS clusters which can be in form of a regional innovation hub zoning. According to these findings, such hubs are best to locate near CBDs, be walkable, and accessible via transit system and accommodate place quality amenities to satisfy KIBS' locational demands. In this essay, I also did observe a negative significant impact of walkability and transit access on the innovation output of SBIR small innovative firms. This might be because walkability and transit access increase the property values and, therefore, make them unaffordable for small innovative firms (Pivo & Fisher, 2011). Such findings on the impacts of walkability and transit access on innovation productivity in vulnerable small firms call for attention to the equity aspects of innovation-supportive urban developments.

According to the findings of the first essay, investments in the transportation systems should go beyond functionality and mobility concerns. Transportation infrastructures should be planned as 'enablers' for creative and knowledge firms. The imperative is to ensure a sound spatial coordination of land-uses and transportation infrastructures to create an 'enabling' physical environment for startups, small innovative businesses as well as other knowledge and creative industries. Planners and policymakers could ensure that the development/extension of a transit line is best leveraged by supporting land use and place making policies for empowering communities' artists, designers, non-profit cultural organizations as well as startups and innovative firms. Some of these policies are well thought land-use plans near transit stations including an active street network and TODs, as well as zoning and incentives to accommodate educational services, co-working spaces, anchor institutions, and workforce development hubs. Such policy suggestions are in line with the findings from the second essay. The second essay provides the empirical evidence confirming the theoretical attempts that explain the mechanism through which TODs could have connection with increased productivity of knowledge and creative firms.

TODs share many of the place-based characteristics presumed to support creative and knowledge firm productivity such as accessibility, walkability and mixed uses (Credit 2018). Considering, However, the research on TOD, agglomeration economies, and creative clusters, there is reason to believe that these types of developments would have broader economic impacts. The second essay provides insight into these relationships by first categorizing TOD station areas by activity diversity, land use diversity and street network design; and second, by testing how these different place-based environments affects creative and knowledge firms' sales.

The second essay's findings indicate that creative and knowledge firms do benefit significantly from locating in TOD station areas. As such, the research suggests planners should integrate TOD oriented policies and regulations with creative and knowledge-based economic development strategies to maximize impacts. Accordingly, the innovation-hub TOD neighborhoods could be planned to harness the productivity of knowledge and creative economy firms. The addition of an innovation-hub TOD to other networked TOD areas could provide the infrastructure to building more resilient and innovative regional economies. Planning for innovation-hub TODs should be based on strategic land use plans, zoning, and incentives to accommodate educational anchor institutions, workforce training centers, co-working spaces, creative and knowledge-led startups, accelerators, and incubators (Katz and Wagner 2014) in addition to existing TOD oriented land use and policy regulations such as mixed use zoning, density bonuses, reduction of parking ratio regulations, placemaking, adopting district plan, Adaptive Reuse Ordinance (ARO) and active transportation design. Such planning efforts can draw upon the successful examples of these regulations. For instance, state-enabled density bonus and incentives successfully facilitated high-density multifamily developments in station areas, which in combination with adaptation of district specific plans spurred TOD growth in Los Angeles (Gabbe 2016).

Additional incentives could include economic development grants for startups, worker training tax credits, and location-based venture capitals. Municipalities should also plan for "upzoning" their hybrid station areas, which already accommodate such services and uses. Accessibility to other universities, CBDs, and airports is critical for this type of TODs in order to allow the Inflow of educated workers and local and global customers; hence, transit services and routes should be planned accordingly.

As cities and regions transition away from an industrial economy, policymakers and planners are continually looking towards the importance of strengthening its knowledge and creative based industries. Although economic geographers and planners have long recognized the value of place in attracting creative and knowledge firms and workers, there has been little attention towards the role TOD could play in these dynamics. This research suggests that there are untapped synergies between TOD and creative and knowledge economies. By integrating planning efforts, planners and policymakers may be better equipped to create places that not only benefit industry clusters, but also provide the framework for a more robust regional innovation ecosystem.

While the first two essays provide the evidence that the walking and transit amenities could support the robust and productive knowledge and creative economy, these two types of firms include a broad range of industries. Despite the consensus on the preference for transit and walking amenities by tech industries and knowledge workers, there is less clear on the extent to which these advantages differ across tech sectoral categories. For instance, IT industries are becoming increasingly less place-based because of increasingly relying on self-employed, part-time, and flexible workforce (Audirac, 2005). On the other hand, the new logistic revolution extends the demand for road and air mobility as the response to the need for fast processing and distribution of time-sensitive high-tech production and goods (Kasarda, 2000). The third essay in this dissertation fwells this gap in the literature by identifying the geography of specialized high-tech zones in the U.S. and analysis of the tech industries location behavior with respect to transportation infrastructure in these zones. My empirical results support theoretical work indicating that different types of high-tech firms seek different transportation infrastructures.

While in general walkability, transit accessibility, road accessibility and proximity to major airports play critical role in location decision of high-tech firms, my results show that these tendencies vary between different high-tech industries. For instance, I found that the mono-high-tech hexagons of professional business services have significantly higher marginal effects for WalkScore and TransitScore, while are significantly more walkable and transit accessible compared to multi-high-tech hexagons. Business services industries include computer/system services and engineering and architecture firms, which are primarily designed to provide services to other businesses, facilities or unrelated companies (Maggioni, 2002). Consequently, they are highly reliant on a specialized workforce to deliver high-order services, concentrate in walkable, and transit accessible CBDs in order to cover a wider market area (Zandiatashbar and Hamidi, 2018). Furthermore, they provide services or immaterial commodities, which unlike traditional manufacturers, do not need or seek cheaper, larger or more peripheral land areas for their manufacturing facilities (Maggioni, 2002). These firms also draw upon the externalities of frequent face-to-face encounters and tacit knowledge exchange that stem from their proximity in dense and walkable CBDs. For these reasons, my results verify that these type of high-tech industries prefer proximity to CBD as well as top R&D universities of their regions.

On the other hand, my results also confirm that not all of high-tech industries prioritize walkability, transit accessibly or proximity to CBDs. For instance, IT, aerospace and pharmaceutical sectors have significantly loIr WalkScore and TransitScore, while aerospace and pharmaceutical sectors significantly place more priority on proximity to freeway access. Unlike the business services, IT employees mostly exchange codified knowledge. Recent studies indicate that online digital interactions could be a substitute for the face-to-face encounters when exchanging codified knowledge (Audirac, 2002; Relph, 1976). Moreover, IT, aerospace and pharmaceutical sectors firms manufacture, process and distribute goods, which need production facilities usually on peripheries (Audirac, 2005). In addition, IT's involvement in e-commerce deepens their demand for air mobility which according to my results IT sectors are generally closer to the major airports of their region (Kasarda, 2000). In addition to IT sectors, my results show that the busiest commercial airports in the U.S. may be emerging as central transport nodes in large metropolitan areas, much as ports and rail terminals Ire in the past. In my analysis, the multi-high-tech hexagons are significantly attracted to the major airports in their regions. Airports are functioning beyond facilitating leisure trips nowadays and their business travels and goods shipment increased rapidly over the past several decades (Kasarda 2000). Hence, major airports are anchoring employment centers and providing a spatial focus for unrelated and diverse firms. My results are in line with pervious analysis of U.S. major airports, which found concentration of employment within 2.5 miles of these airports to be substantial (Appold and Kasarda 2013). Such analyses refocus a question about the nature of major airports within large metropolitan regions in supporting multiple employment nodes.

These findings suggest that more critical attention is required for understanding the relationship between knowledge-based firms and their preferences for transportation infrastructure. The dominant narrative regarding the spatiality of knowledge-based clusters suggests that these industries prefer dense, walkable, mixed use, transit accessible urban environments. My research supports this theory, however only partially. My findings suggest that large numbers of high-tech firms are still attracted to peripheral, auto-centric spaces, which are at odds with transportation policies supporting smart growth management. My results support the concerns about unmanageable growth and congestion are the result of high-tech economic growth.

Despite the long-standing debates regarding economic developments and growth management, the findings demonstrate that many of these high-tech zones may be problematic in terms of their environmental impacts. As the result of these findings, policymakers may need to attend to balanced growth strategies to not only succeed in growing their knowledge economy, but also ensure they address the negative externalities of high-tech economy. The last chapter of this dissertation covers these negative externalities and provide a policy matrix corresponding with them.

Additionally, the third essay includes the most disaggregated high-tech zones and their sectoral typology in the U.S. large regions. Identifying the geography of high-tech zones is a notable contribution to the literature of economic geography. This line of research has been assessing the spatial structure of economic activities as such attributes can form the local and regional development and the location of wealth in the states and the nation (Blakely and Leigh 2009). While the currently economy strong relies on high-tech businesses, there has yet to be an attempt to detect the location of high-tech zones in the U.S. Similar attempts only unleash the cluster of counties encompassing the strong high-tech economic activity, though the location of high-tech zones might be fluid across counties and furthermore a county composes various activities among which one is the economic activity. In this analysis, my findings about the U.S. geography of high-tech zones show that regions are diverse in terms of number and types of high-tech zones. While this diversity of spatial and sectoral structure of high-tech zones in the regions opens venues for future research, the local policy developments should consider these zones as the potential magnet of developments, which could have multiple impacts on the entire region. These zones are the job destinations resulting in increased demands for the daily commutes of the regional workers, while also could exacerbate the social and labor division and the displacement of the local residents. Hence, the local policy developments should place priority in developing the strategies that could maintain a balance between the positive and negative externalities of the growth of their high-tech zones. The last section of this dissertation covers the negative externalities of high-tech zones and provide a matrix of policy recommendations that mitigate such impacts.

High-Tech Zones and Their Negative Externalities (NEs)

In general, there are two sides of argument about creative or high-tech clusters. While one side suggests supportive actions, the other side sheds light on the short term and long term Negative Externalities (NE) of those actions (De Groot, Poot, and Smit 2009; Galloway and Dunlop 2007; Morisson and Bevilacqua 2018; Scott 2006). In this section, I collected these NEs from the existing literature as well as using personal point of view. In this section, I first itemize the NEs and then I develop a policy matrix including multiple recommendations that potentially can mitigate these negative consequences.

NE 1: Shrinking Middle Class; Polarized Labor Division

The labor force needed for the high-tech zones in general would include two classes:

1) Low-wage, unskilled workers: Members of this workforce class would generally participate in the assembly operation tasks which do not require a high level of skill sets or basic knowledge. Moreover, this class is at a higher risk of job insecurity due to the rise of technological advances and production systems shifting to mechanizations (Rifkin 1996). The loss of low wage jobs is more likely to occur in the case of high-tech industries that deal more with high-advanced technologies on a daily basis.

2) *High-Skilled Professionals:* The other class that constitutes the high-tech zone labor market includes high-skilled professionals, educated workforce, or what has been known as the creative

class. The members of this class have been the premium factor in high-tech growth and therefore ample literature has given attention to their life quality amenities (Bereitschaft & Cammack, 2015; Chapain, Cooke, De Propris, MacNewell, & Mateos-Garcia, 2010; Florida, 2014; Scott, 2006).

The focal point of supportive policies for high-tech clusters has been the *High-Skilled Professionals.* While the *High-Skilled Professionals* are necessary for industrial operations, the other class has been forgotten. In addition to the lack of attention in the literature, the more tangible gap happened in terms of wage, job security, social position, Wealth, education, and quality of life (Scott 2006). From the viewpoint of local residents of a newly emerged high-tech zone, local policy makers, in order to harness the regional high-tech economy, rely on attracting outsider educated high-skilled workforce. This inflow migration of *High-Skilled Professionals* would fill the second class while higher portion of original residents might stay in the first class. In other words, leave the original residents with lower education and income out of high-tech growth. The gap between these two classes is increasing resulting from shrinking middle class size and therefore the deepening social division of labor. Hence, socio-economic inequality has become the epidemy among creative cities (Florida 2006, 2017; Frydman and Papanikolaou 2015)**.** The tangible example is Austin's creative city-region, where its high-technology sector grew in the late 1990s. Many in the city have identified an increasing income gap between the creative professionals and the city's poor, many of whom are African American and Latino; 13.1% of the city's population was living in poverty compared with the U.S. average of 12.7%. Furthermore, the average wage in the high-technology sector increased by $26,500 during the 1990s. The average rise in wages for all industries, including high-tech, was only $18,000 — a growth in line with the U.S. average (Comunian 2011; McCANN 2007).

NE2: Housing Unaffordability, Gentrification and Displacement

Housing unaffordability, gentrification and displacement in fact are the most addressed NEs of high-tech clusters with their tangible impact on ordinary local residents (Moulaert 2000; Smith 2002; Swyngedouw, Moulaert, and Rodriguez 2002). After the rise of the knowledge economy, many cities applied place-based strategies in order to foster knowledge-based economic growth. These strategies led to the significant role of real estate development companies in satisfying the strong demand for urban transformations (Bevilacqua, Pizzimenti, and Maione 2017). Thus, instead of building an inclusive and community-led knowledge economy, market forces exposed exclusion and polarization. As McCann (2007) describes, this urban transformation is tied strongly to place-based amenity richness. Such amenity richness also fosters an elevated quality of life that on one side attracts the creative potentials but on the other side increases housing prices. The extensive injection of place-quality amenities into these neighborhoods has become the standard descriptors and has been appreciated by the *High-Skill Professionals* who could afford it. Since the demand side is fulfilled, the housing price increase continues (Fingleton 2008). Therefore, without an adequate pre-growth management agenda in place, this trend of price increase will not stop due to this supply-demand dynamic. In several of the worst cases, this trend ended in a situation where even the skillful professionals could not afford staying in the regions which led to-what Florida (2006) called- the “flight of the creative class” (Florida 2006).

Austin TX is among several examples that face a severe housing price strike after implementation of high-tech cluster supportive policies and growth. The percentage of affordable housing in the Austin metropolitan region dropped from more than 62% in 1991 to under 58% in 1998, a figure 8% lower than the national average for that year (Sustainability

Indicators Project, 2000). The empirical evidence in the U.S. also supports the fact that gentrification (defined as the share of neighborhoods in a region that escalated from the bottom half to the top half in distribution of home prices between 2000 and 2007) positively correlates with the concentration of high-tech industries, share of science and technology workers, artistic and cultural activities across the U.S. metros (Florida 2017).

NE3: Spatial Polarization and Suburban Poverty

The so far discussed NE1 and NE2 potentially can result in spatial colonies of low wageworkers. In several cases, the local residents who faced the NEs of the creative economy Ire also the members of racially disadvantaged communities. Ample evidence also showed that the members of racially marginalized communities tend more to collocate with alike members (M. J. White 1983). For instance, the victims of unaffordability and wage gap in Austin are mostly among African-Americans and Latinos who moved out of the high-tech clusters (McCANN 2007). Another tangible evidence is the spatial colonies of low wage Mexican workers in Silicon Valley in California; the most booming high-tech region of the U.S. Zlolniski's (2006) ethnographic study of Silicon Valley, showed that there is an increasing number of workers who are in an unstable and low-paid status. Several subcontracting agencies are hiring low-wage workers for entry-level custodial works. This working class often includes low wage and undocumented Mexican immigrant workers (Zlolniski 2006). In both cases of Austin and Silicon Valley, they tend to cluster on affordable peripheries, which ultimately form the poor spatial patches in these high-tech regions. On the other side of this NE are the suburban residents of high-tech regions who observe growth of suburban poverty after high-tech growth.

NE4: Unmanageable Growth

Without pre-growth management strategies in place, the growth of the high-tech economy in a region could result in social and environmental harms to those communities. Local decision makers' who are keen to foster the local knowledge economy attract high-tech firms and provide tax abatements, often pay minimum attention to the future negative externalities of their decisions. My results from chapter 4 provide evidence that a large number of high-tech firms are attracted to peripheral, auto-centric spaces, which are at odds with transportation policies supporting smart growth management. For instance, in both Austin and the Bay Area, the high-tech boom led to inequality, traffic congestion, urban sprawl, and environmental issues. However, the local residents; particularly the social justice activists, are always alert to the issues that emerge in their hometowns. In several cases of high-tech clusters, the growth did not match the communities' infrastructure capacities while the pre-growth agenda was not in place (Downs 2005). In Austin, local activists questioned the relative benefits of the city's high-technology boom and the image of the city as a good place to live. The activists blamed the creative clusters and business leaders for inequality and urban sprawl, which have been two of the city's major policy concerns (McCANN 2007). Northern California's Bay Area has one of the most globally Well-known high-tech economies and happens to have the fifth worst congestion in the world (Pishue, 2017). The resistance in the Bay Area against inequality emerged in 2013 opposing the high-tech firms' private tech-shuttles. The protestors who experienced traffic congestion as the result of tech companies reacted to tech shuttles that used the public infrastructure for the for-profit purposes (Rushkoff 2016). Austin's unaffordability, suburban poverty, urban sprawl, and congestion are the result of inadequate growth management that occurred over the past 20 years. In the regions that are attracting high-tech firms like Dallas/Fort Worth in North Texas, the same concern again has been raised among local media. The concerns are about the signals of unmanageable growth leading to growing traffic congestion, sprawl, inequality, and rising housing costs in Dallas Fort Worth Metroplex (Dickson 2018).

NE5: Intense Competition, Lower Trust, and Harms for Social Capital

Generally in the regions where industries are strongly active, the competitive industrial environment is the result of ambitions for growth in the market (Camisón 2004). While this competitiveness has advantages, it could also display several negative impacts in the society, such as lack of trust and lower social capital (Hansen 1992). In the case of high-tech clusters the competition over human capital and ideas is strong which has several negative externalities (Scott 2006). These externalities not only damage the social capital for the local residents but also could increase the chance of failure in the local market and the production chain. The "new economy" production work takes a network of firms following a vertical structure of interaction (complementary businesses). Cut-throat competition, low levels of trust, or a failure to recognize the mutual interdependence of all can lead to dysfunctional outcomes and, thus, damages the required inter-firm network. Similarly, the failures at one level can threaten overall functional capacity at other levels or the whole (Scott 2006).

NE6: Transformation of Local/Urban Identity

Particularly in the regions that majorly concentrate on attracting newcomers and external high-tech megafirms, the local residents' strong concern is transformation of their local cultural identity (ARBAK 2005). Recently, Florida (2017) warned about the growth of a homogeneous place character around the nation. In other words, intense national competition between cities and the regions for developing creative clusters could homogeneously generate overall two city identities; "creative" cities and "supercreative" cities (Florida 2017). Furthermore, while the discourse of the "creative economy" focuses on cultural activities, Galloway & Dunlop (2007) urge for caution about the fact that the "creativity" connotation of the "creative economy" is overriding the cultural values of it. Within the rise of the knowledge economy, the failure to distinguish between cultural and other creative activities causes two negative consequences in a policy sense. First, I lose the ability to measure the actual contribution that cultural (i.e. symbolic) goods make within the knowledge economy context. For example, it is unclear between advertising and opera, both designated as “creative” industries, which has the economic value within the creative economy framework. Second, conflating culture with other creative activities again fails to recognize the distinctive aspect of grassroots and local symbolic cultures. From the viewpoint of local residents, the new economy shifts the identity of the regions by (over)attention to the high-tech firms and attracting newcomer talented human capital. In sum, although Silicon Valley has become the widely desired goal of developments, the public does not less know any local identity that represents the North California Bay Area except the IT and high-tech industrial character.

NE7: Flight of Creative Class, Backward Move

The sum of these NEs ultimately can lead to the “Flight of Creative Class” which could mean a *Backward Move*. “Flight of Creative Class” could be a response to unaffordability, unmanaged growth, lack of trust, and urban sprawl, making a region undesirable for the creative class (Peck 2005). In addition, Scott (2006) points to a character of the creative class, which could justify the “Flight of Creative Class” phenomenon. The creative class or the pools of highly qualified labor are formed and reinforced by the continual in-migration of talented individuals from less-favored areas. These individuals regularly search for the privileged places where they can best realize their career ambitions, hence this does not necessarily stop them from looking for another better place (Menger 1993).The job-hopping habits of engineers in Silicon Valley is an example of talented workers desire for switching firms and places. Ultimately, Scott (2006) points out to a foundational conundrum in the creative class discourse. In his viewpoint what can make creative cities lies in the production system, hence he describes that:

“Any city that lacks a system of employment able to provide these individuals with appropriate and durable means of earning a living is scarcely in a position to induce significant numbers of them to take up permanent residence there, no matter what other encouragements policy makers may offer. This means that any viable developmental program focused on building a creative city must deal—at a minimum—with setting up a local production system, training or attracting a relevant labor force, appropriate programming of urban space, and ensuring that all the different elements involved work more or less in harmony with one another.” (Scott 2006, 11)

Policy Matrix

The policy matrix presented below includes multiple recommendations that could mitigate or prevent the aforementioned NEs. I developed this matrix using and modifying the existing policies designated for the abovementioned NEs, successful cases in the, U.S. and personal recommendations.

Table 19: Policy Matrix (Morisson and Bevilacqua 2018; Muro and Puentes 2004; PolicyLink n.d.)

Policy	Objective(s) and Agenda	**NE#**
Entrepreneurship + Affordable Housing Policies	● Mixed-residential and retail/office properties: *by integrating the concept of entrepreneurship in Affordable Housing Developments, while the space is allocated for residential use, the properties can also have retail use to support owners'/renters' entrepreneurial activities. This could be in form of* ***mixed-condo retailer developments*** *that the condominiums' residents could also startup business activities in the retail space.* ● Affordable Properties in the High-Tech Hubs: *In several cases like Austin, TX, or Chattanooga, TN, the local policy makers consider Affordable Housing Developments in the high-tech districts in order to mitigate the property value rise.* ● Access to Workforce Development Hubs: *the affordable housing policies need to cope with the new forces of economic development. Accessibility to the educational institutions and workforce training opportunities should be prioritized for the location of the designated properties for the housing assistance incentives.* ● Dense and Multifamily Rental Properties: *The multifamily rental properties in tech-hub cores would be a better option compared to single-family homeownership assistance programs. Such properties would allocate better access to jobs while development of single-family houses could contribute to sprawl and congestion.*	NE1 NE2 NE3 NE4 NE7

Identity Zones	● Protect And Empower The Local Urban Identity: *To protect and empower the cultural identity of the regions, local leaders can develop form-based codes for the historical blocks/neighborhoods in the regions or cities to prevent the intervention of high-tech industrial activities and protect and empower the local historical identity. A portion of the tax benefits of high-tech growth could be allocated to the urban branding strategies and grassroots cultural activities in these zones. Ultimately, these zones could become the designated and profitable cultural nodes in the high-tech zones.* ● Identity Zones in High-Tech Districts: High-tech districts could include the identity zones, if the zones are implemented at the block level. *Place branding strategies that support local grassroots cultural activities and amenities for non-economic public gatherings and events will help mitigate NE5 as Well.*	NE5 NE6
Local Labor Empowerment Policies/Initiative	● Tech-Based Training for the Local Labors: *empowering the local labor market is a more resilient strategy than over-concentration on attracting the outsider talented workforce. The local policy makers can develop and offer several tax cut incentives to tech megafirms to participate, provide facilities and partner with the local universities to train the local young generation for the tech jobs. The coalition of industry, university and government could form to continue and oversee the long-time implementation of such policies.*	NE1 NE2 NE3 NE7
Diversification	● Diverse Industrial Activities: *although the high-tech clusters form as the result of high-tech anchors, local decision makers could support diverse economic activities. The policy solution for the issue of an intense competitive environment in places with intensive high-tech activities would be supporting the nonhigh-tech activities along with high-techs such as retail services, the cultural activities and local grassroots arts. This not only mitigates NE5 but also supports the local entrepreneurships of non-high-tech workers.* ● Diversification of Firms by their Accessibility Needs: *The results of my analysis in chapter 5 show that high-tech industries have mixed preferences in terms of active and non-active modes of transportation. Professional services are attracted to transit accessible and walkable areas and are the industries that also can collocate and provide services to non-similar firms. This economic diversification can balance the needs for both active and non-active mobility facilities.*	NE5 NE6

Pre-Growth Agenda	*Policy makers should use a pre-growth agenda with supportive policies for attracting high-tech companies. This agenda should include the following:* ● Limiting outward expansion: *Implementing smart growth planning policies to encourage higher density development, concentrating housing and employment can mitigate several suburbanization negative consequences. There is also a focus on promoting mixed-use zoning, increasing accessibility for pedestrian traffic, preserving open spaces for agricultural and park uses, and reusing and improving existing infrastructure rather than developing new construction. These smart growth policies also attempt to tackle poverty and revitalize communities that have lost their vitality.* ● Access to knowledge: *Access to knowledge, quality education, workforce hubs, and jobs are critical components of this agenda.* ● Affordable rental housing*: affordable rental multifamily housing in the high-tech districts mitigate the displacement issue while coping with the smart growth goals in limiting outward expansion.* ● Multi-modal transportation systems: *As growth happens, congestions are inevitable consequences. Investment in a multimodal transportation system and increasing the non-auto inter-city mobility mitigate congestion and suburban poverty.*	NE1 NE3 NE4
Inclusive Leadership Coalition	● Partnership of a Wide Range of Actors: *The best approach is to draw upon a coalition that includes a wide range of actors to develop an entrepreneurial high-tech region. The members of such a coalition could be local 501(c)3 organizations, key high-tech firms, universities, social justice activists, and the city's or region's official decision makers. The few successful examples that could overcome the majority of the aforementioned NEs drew upon a designated task force formed by the mayor for innovation supportive urban and policy developments. Such a task force could enable the more inclusive and collective decision making. The coalition's main responsibility would be* ***defining the vision and pwellars for knowledge-based urban developments****,* ***overseeing the associated policies and developments*** *and* ***advocating the equity and inclusiveness.*** ● Public Private Partnership: *Forming such a coalition and including the local stakeholders such as for-non-profit foundations and the economic anchors of the cities or regions will also establish the environment supportive for the public-private partnership. The partnership is a key factor in initiating, forming, and implementing local labor empowerment policies and activities.*	NE1 NE2 NE3 NE4 NE5 NE6 NE7

Smart mobility plan, City's Maker Economy	● Larger Functional Labor Market by Expanding Commuting Zones: *A transportation system that targets expanding its commuting zone through a multimodal mobility plan, will enable jobs-to-workers and workers-to-jobs accessibility. The local public transportation infrastructure such as streetcars, transit systems, subways, and regional or intercity systems, like a high-speed rail that enable outward reach of metro areas also mitigate traffic congestion.* ● Enhanced Access to Workforce Training Anchors: *The local/regional mobility plans in the knowledge economy era should enhance accessibility to the workforce hubs and entrepreneurial training anchors, such as educational institutions and business incubators, particularly for the spatial colonies of low - wage worker families. A regional innovation system could be an ideal approach, In such system the workforce development anchors are the key nodes of destination which are provided with enhanced transportation infrastructures.* ● Connecting Land-Use Policies and Transportation Infrastructures: *As part of smart growth policies, the alignment of land use policies and the transportation system will combat the sprawl issue. In addition to the higher density in proximity to transit areas (Well known as Transit Oriented Developments), locating affordable housing and workforce development centers within the station accessible areas could help foster the knowledge economy through transportation policies.*	NE1 NE2 NE3 NE4 NE7
Tax Reforms	● Density and mixed-use supportive tax plans: *substituting the property tax with the land tax could encourage mixed-use dense developments* ● Multimodal transportation infrastructure development: Policy makers can support developing a multimodal system by simply *redirecting the gas tax towards diverse modes of transportation (Public Transit and High-Speed Rail)* ● Quality education in poor neighborhoods: *allocation of tax subsidies for quality education and schools in disadvantaged neighborhoods* ● Entrepreneurial Tax Bundle: *design and designate entrepreneurial tax program packages for the poor families, i.e. the property tax relief for startups, allocating supplemental payments of the negative income tax to incubate an entrepreneurial activity and/or Small Business Incubator Tax Credit in poor neighborhoods*	NE1 NE2 NE3 NE4

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