Transit-induced Agglomeration and Employment Opportunity: A Spatial Econometric Analysis of Skill- and Industry-specific Job Clusters in Philadelphia, PA

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Abstract

The impacts of transit improvements on agglomeration economies have been studied repeatedly in regional science and urban planning. However, none of the studies focus specifically on the effect agglomeration associated with transit has on socially and economically disadvantaged groups. To fill this gap, this study primarily sheds light on the issue of low-skilled labor force's opportunities related to transit-induced economic development. More specifically, we investigate the heterogeneous impacts of transit-induced agglomeration on job opportunities for employees with different skill levels and in different service sectors in Philadelphia, PA. For this study, we chose Location Quotients (LQ) to measure first skill- and then industry-specific agglomeration. We estimate spatial econometric models to analyze direct and spillover impacts of transit-induced agglomeration on job opportunities for low- and high-skilled jobs and different industries. Our results show that transit-induced agglomeration has a negative direct effect on low-skilled jobs, and a positive direct effect on high-skilled jobs. These results imply that the economic development revitalization strategy heavily favored high-tech and knowledge-based firms leading to a concentration of high-skilled workers and an underrepresentation of low-skilled workers in the urban core areas. This suggests less accessibility to job opportunities for transit-dependent low-skilled workers. The presence of positive spatial spillover effects of low-skilled workers further indicates that the concentration of economic activities around transit stations absorbs economic resources from neighboring areas. Overall, the revitalization projects have caused uneven and inconsistent local economic conditions across the entire metropolitan area.

1 Introduction

Public transit infrastructure promotes agglomeration economies and stimulates economic activity (Venables, 2007; Chatman et al., 2016). Urban density combined with the availability of an extensive public transit network improves accessibility to jobs and helps employers recruit employees with much-needed skills. Furthermore, a higher employment density facilitates exchanges of information and innovative ideas among corporations, institutions, and employees. It creates opportunities to share knowledge face-to-face through casual meetings as well as professional conferences (Marshall, 1920; Chatman and Noland, 2011). In addition, public transit is essential to for low-income groups of the population to access to jobs and other various activities because of the heavy financial burden of car ownership (Glaeser et al., 2008). Thus, the public transit network increases job opportunities through higher densities and improves job accessibility through improved commuting opportunities.

Philadelphia, Pennsylvania has one of the most extensive and well-connected transit systems in the US with the 6th highest transit ridership (Freemark, 2023). Its regional transit system, the Southeastern

Pennsylvania Transit Authority SEPTA (2023), serves 5 counties within the metropolitan area. Small and Gomez-Ibanez (1999) find that specifically low-wage workers are more likely to be dependent on public transit to commute to work in Philadelphia. Accordingly, the city could improve equity in the labor market by implementing policies that provide more job opportunities to a marginalized labor group in districts that are well connected to public transit modes (Brown et al., 2014).

Since the 1990s, Philadelphia transitioned from a heavy manufacturing-based economy to a major service economy (Johnson et al., 2002; Weaver, 2016). More recent urban revitalization projects redeveloped deindustrialized sites into vibrant and innovative economic centers. Economic development strategies, such as empowerment zones (EZ), aim at improving the city's competitive environment to attract multinational high-tech and knowledge-based corporations(Hyra, 2012; Wiig, 2019). During the transition to a service-oriented economy, many traditional manufacturing and blue-collar jobs were replaced with jobs that require higher educational proficiencies and different skills than those in traditional manufacturing (Graham and Marvin, 2001). Hence, we expect to find low-skilled jobs are less available in these newly developed areas since city officials prioritized knowledge-based and innovative businesses requiring highly educated professionals. As such, while Philadelphia's revitalization efforts created superior public transportation accessibility in geographically selected zones, it also marginalized and low-skilled workers (Philadelphia, 2023). In other words, although transit availability improves job accessibility for low-skilled workers relying on transit modes to commute to work, recent developments around transit nodes works against them as job requirements shifted towards knowledge-based and high-skill industries.

There are many studies focusing on the impacts of transit-oriented infrastructure on agglomeration economies (Chatman et al., 2016; Credit, 2019) and a wide consensus that transit improvements facilitate agglomeration and stimulate employment (Chatman and Noland, 2014; Yu et al., 2018). Other studies question the effectiveness of transit-oriented development on employment outcomes such as wages and turnover rates (Shen and Sanchez, 2005). Most studies, however, address public transit-related gains in terms of economic efficiency (McCann et al., 2001), while fewer studies focus on the impact agglomeration economies have on a poor population or workers with a low education level. More specifically, many studies of agglomeration economies examined overall employment growth, while very few studies took a more detailed look at which specific groups of the labor force are the main beneficiaries and which skill levels are preferred (Lindley and Machin, 2014). To fill the gap in the relevant literature, our study contributes to the understanding of how transit-induced agglomeration impacts low- and high-skilled job opportunities in the Philadelphia metropolitan area. In addition, our study compares the effects of agglomeration on service industries with large percentages of low-skilled workers to the ones that have predominantly high-skilled workers.

The next section reviews the relevant literature on agglomeration economies, public transit, and equity, followed by an introduction of issues related to urban revitalization and economic changes in Philadelphia. The study area and the data sections explain the choice of geographical units of analysis and describe the variables used, while the methods section provides a methodological justification for applying a spatial econometric model. Finally, we interpret the model results, discuss policy implications and make policy recommendations based on our findings.

2 Relevant Literature

2.1 Agglomeration economies and transit infrastructure

Firms, employees, and economic activities often cluster in specific locations. Agglomeration economies are geographic concentrations of such economic actors that stem from positive externalities. Economies of scale and reduced transportation costs, the result of high urban densities, increase productivity and create employment opportunities (Marshall, 1920; McCann et al., 2001). Wages are higher in the presence of agglomeration economies and increase as the market size grows. Moreover, businesses can provide goods and services at lower, more competitive prices, taking advantage of economies of scale. The combination of higher nominal wages and lower prices increases real disposable incomes, making agglomeration areas more attractive places to live and work (Krugman, 1991; Fujita et al., 2001).

Marshall (1920) in his seminal work defined three sources of agglomeration economies. First, firms can more efficiently share resources in higher-density environments. Denser areas can minimize the costs of intermediary goods and transportation. Second, employers can more easily find high-skilled and specialized workers in a city exhibiting agglomeration economies than in widely dispersed urban environments. And last, urban agglomerations facilitate the exchange of innovative ideas and new technology. High-density and transit-oriented environments encourage face-to-face interactions and formal and informal meetings among firms, institutions, and employees (Glaeser et al., 2004; McCann and Shefer, 2004).

Recent studies suggest that public transit infrastructures induce agglomeration economies by increasing densities and accessibility (Venables, 2007; Chatman and Noland, 2011; Credit, 2019). Chatman and Noland (2014) and Glaeser et al. (2004) argue that transit improvements introduce the three Marshallian sources of agglomeration described above by creating a denser urban environment. Scholars refer to agglomeration economies stimulated by transit infrastructure as transit-induced agglomeration (Graham, 2007; Venables, 2007). Nevertheless, the impacts of transit on agglomeration may vary depending on prevalent industry sectors, existing urban land uses and, of course, available transit services (Chatman et al., 2016; Yu et al., 2018; Credit, 2019). Information services, finance, insurance and real estate, and science and technical service sectors are strongly associated with the proximity to rail transit stations, while the transit-induced agglomeration effects are less pronounced for manufacturing firms and retail stores (Chatman et al., 2016; Yu et al., 2018). Glaeser et al. (2001) suggested that a city with a high-quality transit system attracts human capital as seen in industry sectors with a large share of high-skilled workers.

There are also regional variations in the impacts of transit on agglomeration economies. For example, transit effects are stronger in Portland, OR than in Dallas, TX. Portland's land use policy promotes urban densification, such as Transit-Oriented Development (TOD) and Urban Growth Boundary (UGB), whereas Dallas does not have comparable policies (Chatman et al., 2016). In Philadelphia and Boston, businesses in most industries are more likely to be located in areas within reasonable walking distance to transit stops, rather than areas remote from the facilities. In general, more mature, multimodal transit services and historic, walkable streets tend to enhance transit accessibility (Credit, 2019).

2.2 Recent issues of public transit, urban revitalization, and equity

Public transit accessibility is a widely debated equity issue (Iseki and Taylor, 2010; Brown et al., 2014; Aman and Smith-Colin, 2020). The more disadvantaged, low-income populations tend to be more dependent on public transportation modes to gain access to work, shopping, and other desired locations. Low-wage or low-skilled workers are more likely to commute to work by transit than their wealthier counterparts, because of the financial burden of vehicle ownership (Small and Gomez-Ibanez, 1999; Glaeser et al., 2008; Wang and Woo, 2017). Therefore, poor transit accessibility could be a significant barrier for these already disadvantaged workers to obtain access to employment opportunities (Ong and Houston, 2002; Brown et al., 2014).

More recent trends of urban revitalization may have undermined transit accessibility for disadvantaged groups of the population. Before the 1990s, jobs were often dispersed to wealthier suburbs in US metropolitan areas, while marginalized workers concentrated in the inner cities (Kain, 1968; Ihlanfeldt and Sjoquist, 1998). The current wave of urban revitalization projects in rising cities differs from earlier efforts as it focuses on high-density developments in the Central Business Districts (CBD) and urban cores that enhance walkability and transit accessibility. The outcome was often the replacement of small local businesses and industrial firms with multinational headquarters and innovative enterprises (Wiig, 2019). Land use changes also catalyzed the trend by converting industrial uses to commercial and office spaces (Curran, 2007; Hurst and West, 2014). As a direct result, those urban revitalization efforts naturally favored high-skilled workers over low-skilled workers (Glaeser et al., 2004; Sun and Fan, 2018; Wiig, 2019).

The revitalized cities with efficient and extensive public transit systems became a magnet for a well-educated work force (Glaeser and Mare, 2001). Public transit facilities are concentrated in central urban neighborhoods, where the share of high-skilled jobs has grown rapidly in recent years (Glaeser et al., 2008; Brown et al., 2014). Urban renewal and transit-oriented developments displaced low-skilled jobs from the urban centers, which potentially weakens job accessibility for transit-dependent workers. The trends described here are concerning and raising equity issues, as disadvantaged groups of the population are experiencing poorer transit accessibility (Ferm, 2016; Wexler and Fan, 2022).

2.3 Agglomeration economies: A solution for economic efficiency, not for equity?

There is consensus that agglomeration economies improve economic efficiency, but it is questionable whether agglomeration economies improve economic equity (Glaeser and Mare, 2001; Ferm, 2016). Cities with agglomeration economies have competitive production capacities and high-quality amenities that attract highly educated workers (Glaeser et al., 2001, 2004). At the same time, the rapid growth of innovative companies increases the demand for a workforce equipped with sophisticated and specialized skills and an environment that encourages the facilitation of exchanging ideas and information about cutting-edge technologies (Porter, 1990; McCann and Shefer, 2004; Kerr et al., 2017). Often, land use planning with the purpose of promoting agglomeration economies replaced industrial lands with office spaces where multinational corporations are located (Wiig, 2019). Hence, revitalized cities transitioned from manufacturing centers to high-productivity service-based economies (Weaver, 2016).

High-skilled workers are a key driving force for sustained productivity growth (Glaeser and Mare, 2001). Furthermore, high-earning employees prefer cities offering plentiful urban amenities, such as effective transit services, entertainment, parks, and gourmet foods (Glaeser et al., 2001). Productivity gains and urban amenities are capitalized in the real estate markets, reducing the availability of affordable housing for low-income earners (Glaeser et al., 2004; McCann and Shefer, 2004). In addition, new clusters of knowledge-based firms often displace local small businesses and industrial firms from the central urban areas (Ferm, 2016). Consequently, urban agglomerations may significantly contribute to the sources of inequity in employment (Wiig, 2019).

2.4 Contributions and research questions

This research contributes to the discussion of how public transit improves economic opportunities for various groups of the workforce. Previous relevant studies of agglomeration economies focused mainly on economic efficiency (Glaeser et al., 2004) and only a few studies explicitly explore the effect of agglomeration economies on low-income or low-skilled labor forces (Lindley and Machin, 2014; Sari, 2015). More specifically, our study contributes to the existing literature by analyzing the effects of transit-induced agglomeration on job opportunities for workers with varying skill levels, particularly in service industries. The literature provides ample empirical evidence about the positive impacts of transit on agglomeration economies (Mejia-Dorantes et al., 2012; Chatman et al., 2016). We argue, however, that it would be informative for policymakers to better understand how transit-induced agglomeration affects different segments of the labor force.

We are trying to answer two specific questions: First, are there adequate low-skilled job opportunities in areas with high transit-induced agglomerations? Second, does transit-induced agglomeration affect blue- and white-collar service sector employees differently? To answer these questions, this study focuses on the impacts of transit-induced agglomeration on low- and high-skilled job concentrations. By answering these two specific questions, we also look into whether each of the selected service industries benefits from transit-induced agglomeration.

3 Study area

We chose the Southeastern Pennsylvania Transportation Authority (SEPTA) region[1] as our study area to include all of Philadelphia's extensive and well-connected transit network. Philadelphia has the 6th largest transit ridership in the US (Freemark, 2023), and its popularity can be explained, by the fact that it is one of only two American metropolitan areas (the other is the Boston area) offering all five types of public transportation modes, which are subway, light rail, commuter rail, buses, and trolleys. Southeastern Pennsylvania Transportation Authority (SEPTA) provides transit services for almost 4 million people throughout 5 counties within the Philadelphia metropolitan area (SEPTA, 2023). Credit (2019) concluded that the extensive,

[1]The Southeastern Pennsylvania Transportation Authority (SEPTA) region includes Philadelphia County, Delaware County, Montgomery County, Bucks County and Chester County. Whenever we make a reference to our study region as Philadelphia in the reminder of the paper, we are referring to the five county SEPTA region.

cohesively connected, and mature multimodal transit networks combined with Philadelphia's historic and walkable streets contributed to the creation of new businesses in transit accessible areas. As such, the transit infrastructure positively impacted the regional economic development in the five-county region.

Travel choice data shows that lower-income workers tend to be more dependent on public transit than the rest of the labor force in Philadelphia. About 12% of workers with annual incomes of $25,000 or less use public transit to get to work, while the transit ridership rate for workers with an income greater than $75,000 levels off to below 8% (Figure 1). Transit commuters also have the lowest vehicle-ownership rate in Philadelphia of 67% (Figure 2). Though some of the transit riders may simply prefer not to own a car, many low-income residents are unable to own a car or forced to give up car ownership due to the considerable financial burden. Transit services are therefore essential for them to commute to work.

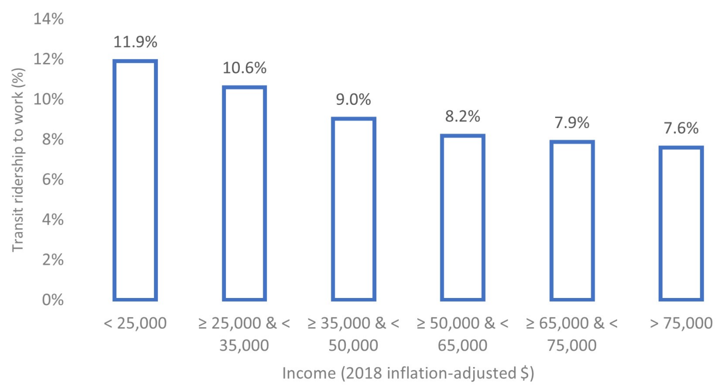

Figure 1: Transit ridership by Income (2013-2018 ACS data)

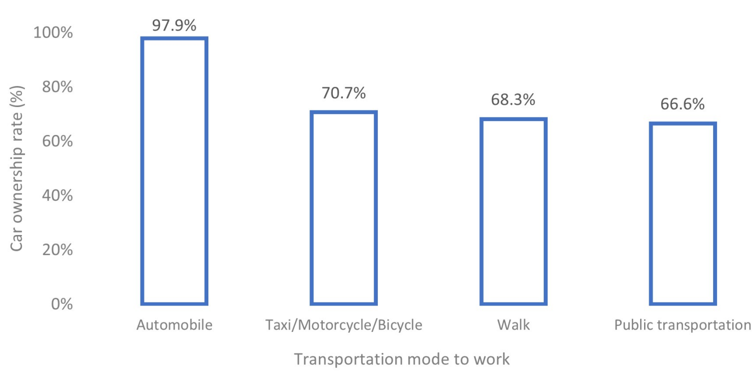

Figure 2: Commuting mode by car ownership (2013-2018 ACS data)

The city has experienced a significant industrial transformation over the past 40 plus years. Manufacturing was the predominant industry in Philadelphia until the 1980s (Weaver, 2016), but a restructuring of the economy accelerated by a decline of steel production and other manufacturing-based industries, resulted in vast areas of vacant industrial lands. The city responded by promoting brownfield redevelopment policies to turn abandoned sites into economically viable commercial uses, such as office and retail spaces and housing opportunities. These projects have also focused on connecting the redeveloped lands with the fast-growing employment centers and with the growing transit network (Johnson et al., 2002). At the same time, empowerment zones (EZ) aimed at revitalizing deindustrialized lands by means of promoting service sector activities. With EZ, the city officials envisioned an improvement of the city's global standing (Wiig, 2019).

These EZ are mainly located in major central urban areas, including Philadelphia's Center City, the University City, the International Airport, and the Navy Yard, to remedy the chronic urban decline. One of

Philadelphia's revitalization strategies includes improving the public transportation infrastructure to connect these EZ with other parts of the city (Philadelphia, 2023). Attracting multinational firms, while increasing the economic viability in EZ, also demands specific labor skills and innovative technologies (Hyra, 2012; Wiig, 2019). Empowerment Zones have location-specific advantages that lead to a concentration of the city's resources, such as economic development incentives and transportation infrastructure investments. In contrast, areas outside these selected EZ often experienced economic decline. As a result, Philadelphia's economic development strategies contributed to inequality between commercial districts (Graham and Marvin, 2001).

The economic restructuring and revitalization strategies contributed to a rapid increase of employment opportunities for people with college degrees. The percentage of high-skilled workers grew from 38% to 46%, while the share of the low-skilled labor force fell from 37% to 30% between 2006 and 2018 (Figure 3). Health care (19% of total employment), education (9%), professional, scientific, and technical services (9%), and finance, insurance and real estate (7%) are now the predominant industries in Philadelphia (Table 1). The common factor amongst these advanced service sectors is that they primarily employ college-educated workers. Lower-skilled workers find employment opportunities in more traditional blue-collar sectors, such as retail trade (10%) and accommodation and food (7.6%). The City of Philadelphia targeted service industries as part of its urban revitalization efforts (Weaver, 2016) as seen in Table 1. Knowledge industry employment (enterprise, financial, professional services, and information jobs) makes up 21% of the total employment in 2018.

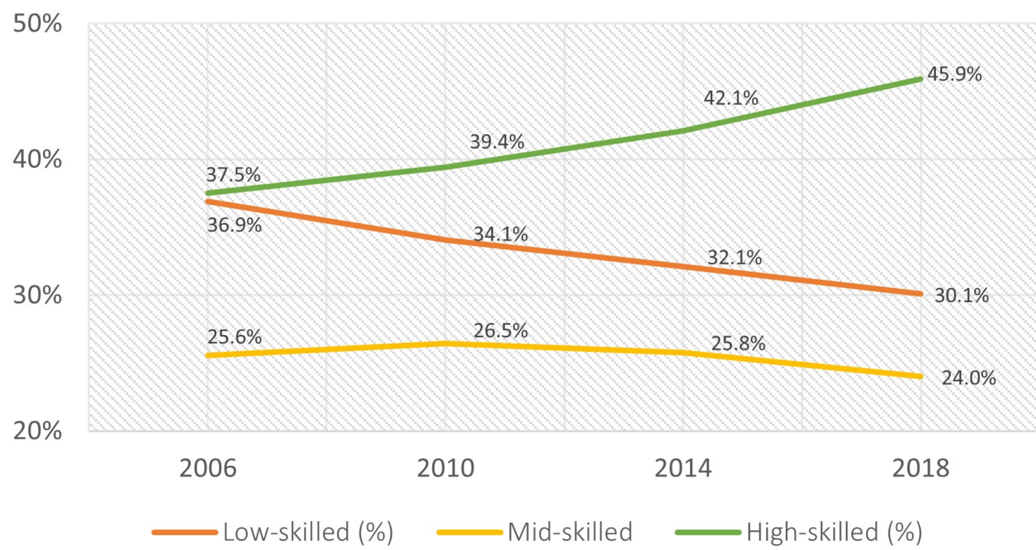

Figure 3: Labor force trends, 2006-2018 (ACS datasets)

Table 1: Industrial structure in Philadelphia metro area, 2018 (LEHD data)

Industry	**NAICS Code**	**Jobs**	**Job share (%)**
Agriculture, Natural resources, and Mining	11, 21	6,791	0.3%
Construction	23	82,948	4.1%
Manufacturing	31-33	125,691	6.3%
Wholesale trade	42	79,169	3.9%
Retail trade	44-45	200,387	10%
Transportation/Warehousing/Utilities	22, 48-49	70,460	3.5%
Information	51	44,018	2.2%
Finance, Insurance, and Real estate	52-53	143,460	7.1%
Professional, Scientific, and Technical Services	54	178,068	8.9%
Management/Enterprise	55	49,526	2.5%
Administrative/Waste	56	123,983	6.2%
Education	61	186,639	9.3%
Health care	62	385,156	19.2%
Art/Entertainment/Recreation	71	35,766	1.8%
Accommodation and Food	72	153,089	7.6%
Public administration	92	66,364	3.3%
Other services	81	75,230	3.7%
Total		2,006,745	100%

Philadelphia, including its CBD, has an uneven spatial distribution of both low-skilled and high-skilled jobs (see Figure 5 and Figure 4). The suburbs adjacent to the city have the mostly high-skilled jobs, whereas the outer suburban areas of the metropolitan region have higher proportions of low-skilled jobs. We use the Local Indicator of Spatial Association (LISA, Figure 5 and Figure 4) to visualize statistically significant spatial relationships between Census Block groups (LeSage and Pace, 2009). It shows that high-skilled jobs cluster (High-High) in the suburbs near the city boundary (Figure 4). The first-ring suburban areas have a dense transit network and good job accessibility. On the contrary, the LISA in Figure 5 shows that low-skilled jobs are more likely to concentrate (Low-High) outside of those areas with good transit accessibility. The significant negative correlation coefficient of -0.7 between low-skilled and high-skilled jobs is consistent with our initial findings. By comparing the maps shown in Figure 5 and Figure 4, the central issues addressed in this research are visible: high-skilled jobs are plentifully available in close proximity to public transit lines, while low-skilled jobs, with the exception of the CBD, cluster in areas further away. In other words, the existing land use pattern points towards a significantly lower transit accessibility for low-skilled workers. In return, this raises equity issues for the low-skilled labor force as the high-skilled work force benefits from transit-induced agglomeration, while the more transit-dependent group, the low-skilled work force, faces lower job accessibility near transit lines.

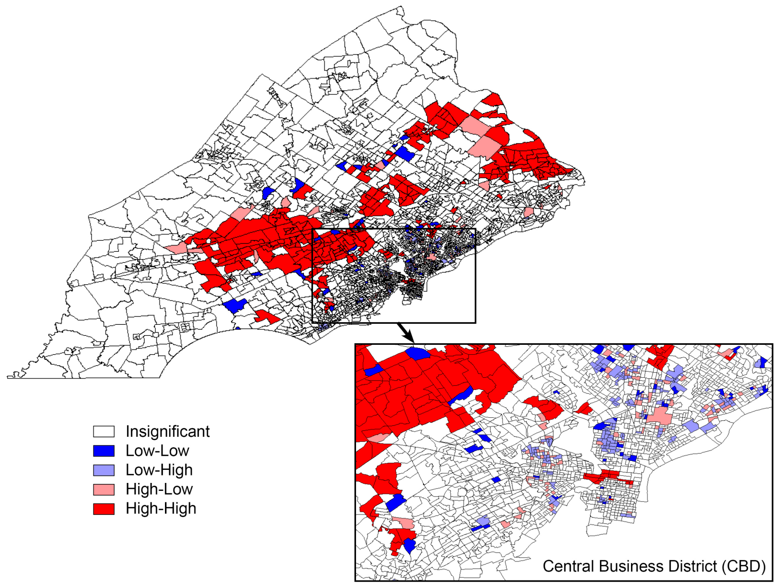

Figure 4: Local Indicator of Spatial Association (LISA) map for high-skilled jobs

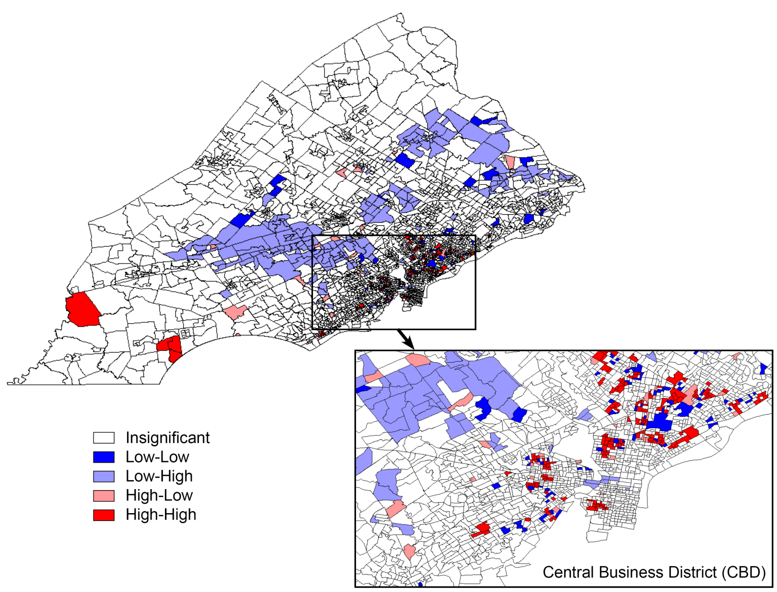

Figure 5: Local Indicator of Spatial Association (LISA) map for low-skilled jobs

4 Data

For this study, we rely on multiple different data sources. All data on employment, public transit, the built environment, and demographic characteristics of the population in 2018 are at the Census block group level. Census block group level data have the advantage that they are widely available, while still being small enough geographic units that explain spatial variations accurately and in greater detail as is the case in the Philadelphia metro region with a total of 2,963 block groups. All employment and industry mix data come from the Longitudinal Employer-Household Dynamics (LEHD) dataset. The most crucial information in the dataset is the number of jobs by educational attainment. We define jobs that require either no educational credentials or a high school diploma as low-skilled jobs. On the other hand, high-skilled jobs require at least a bachelor's degree. This distinction of skill levels is crucial for our study as workers with a lower education level often face barriers in the labor market due to the lack of specialized skills (Merlin and Hu, 2017).

Furthermore, the LEHD dataset has industry sector-specific employment information. The major white-collar industries in Philadelphia are healthcare (62), education (61), and the knowledge sectors, which includes information (NAICS 51), finance and insurance (52), real estate (53), professional, scientific and technical services (54), and management of companies and enterprises (55). These white-collar industry sectors hire disproportionately high shares of high-skilled workers. Together, they constitute 45.9% of the city's employment in 2018 (Figure 3). The city's most important blue-collar industries are retail trade (44-45) and accommodation and food services (72). Low-skilled workers are predominant in these blue-collar industry sectors, which make up 30% of Philadelphia's employment (Figure 3).

We follow Graham (2007) in calculating transit-induced agglomeration based on travel times, job opportunities and transit accessibility factors. First, the General Transit Feed Specification (GTFS) dataset includes information about stops, routes, and schedules for all public transit modes. The dataset allows us to measure travel times between trip origins and trip destinations for all trips using public transit. Next, we employ two publicly available spatial datasets. The Pennsylvania Department of Transportation (PennDOT) and Delaware Valley Regional Planning Commission (DVRPC) Geographic Information System (GIS) data allow us to identify key built environments at the Census block group level. More specifically, we calculate distances from each block group to the CBD, to highway entries, the international airport, and to all universities in Philadelphia. The DVRPC GIS data also includes detailed information on land uses which we use to estimate the proportions of commercial land use in Census block groups. Last, the US Census Bureau's American Community Survey (ACS) data includes sociodemographic characteristics affecting employment, such as education level, race and ethnicity, and poverty status.

5 Methods

Following the relevant literature, we use spatial econometric techniques to estimate the direct and spillover effects of transit-induced agglomeration on jobs (LeSage and Pace, 2009; LeSage, 2014). We use location quotients (LQ) as indicators for job opportunities for different labor force groups. We define the location quotient for this study as the ratio of the percentage of an employment group in a Census Block group over the percentage in the metropolitan area as a whole (Bogart and Ferry, 1999). Effective densities measure the level of transit-induced agglomeration, which are a combination of job density in an area and jobs in all other areas that are within a reasonable commuting time by transit (Graham, 2007).

5.1 Variables and indices

Our research focuses on the impacts of transit-induced agglomeration on the availability of jobs. Available jobs are grouped according to their skill level requirements into low- and high-skilled jobs. In addition, we investigate the relationships of transit-induced agglomeration and the availability of jobs in the three major service industries, namely, knowledge-based industry sectors (51-55), retail trade (44-45), and accommodation and food services (72). In the next step, we calculate the location quotients ($\mathrm{LQ}_{\mathrm{e,i}}$) for each skill level and each industry sector of interest for each Census block group (i). These location quotients ($\mathrm{LQ}_{\mathrm{e,i}}$) allow us to measure the employment concentrations expressed by skill level and by industry as:

$$LQ_{e,i} = \frac{E_{e,i}}{E_{t,i}} \Big/ \frac{E_{e,m}}{E_{t,m}} \tag{1}$$

where:

$LQ_{e,i}$ = skill- and sector-specific location quotient for Census block group i

$E_{e,i}$ = skill- and sector-specific employment in Census block group i

$E_{t,i}$ = total employment in Census block group i

$E_{e,m}$ = skill- and industry sector-specific employment in the Metro Philadelphia

$E_{t,m}$ = total employment in the Metro Philadelphia

e = skill-level and industry sector employment

i = Census block group

m = Metropolitan area

Location Quotients (LQ) have a long tradition in studying spatial concentrations of employment or demographic groups (Bogart and Ferry, 1999; Rovolis and Tragaki, 2006). For instance, Glaeser et al. (1992) and Yu et al. (2018) used LQs to measure industry-specific job concentrations in regional studies. In our study, we apply LQs to measure whether low-skilled and/or high-skilled jobs are under- or overrepresented in a block group (i).

Altogether, we calculate five types of location quotients, two for employment concentrations by skill level and three for the selected major service industries (Table 2). Using five distinct LQs allows us to see whether transit-induced agglomeration impacts concentrations differently for i) jobs requiring high skill levels versus jobs requiring low skill levels, and ii) jobs in knowledge industry sectors which mostly require a college degree versus jobs in retail trade and accommodation and food services, which have mostly lower educational attainment requirements (Watson, 2017). Using LQs to identify job opportunities for low- and high-skilled workers or for industry-specific jobs then allows us to identify whether jobs are evenly available in Census block groups for different parts of the population with respect to skill level and to industry. Venables (2007) was among the first to introduce the concept of public transit-induced agglomeration. The economic productivity in an area increases as firms and associated jobs, supported by improvements of public transit, cluster around transit stations. Access to jobs with a reduction in commuting costs leads to an increase in real wages. We follow closely Graham (2007), who developed an indicator for measuring transit-induced agglomeration, the effective density (ED_i). An area's i effective density (ED_i) is calculated based on its own job density in square miles ($\frac{E_i}{A_i}$) and the number of jobs (E_j) in neighboring areas j adjusted by an impedance factor ($f(C_{ij})$). Specifically, the effective density is defined as:

$$ED_i = \frac{E_i}{A_i} + \sum_{j,\ i \neq j} E_j f(C_{ij}) \tag{2}$$

where:

E_i = number of jobs in Census block group i

A_i = square mileage of Census block group i

E_j = number of jobs in neighboring Census block group j

$f(C_{ij}) = e^{-bt}$ = impedance function with t $\leq$ 45 minutes

According to equation 2, available jobs in near-by Census block groups (E_j) are discounted by an impedance function, $f(C_{ij}) = e^{-bt}$, which accounts for the fact that job availability decreases with travel time, where b is the distance decay parameter (Levine et al., 2012), and t is the commuting time in minutes it takes to get from i to j by public transit. As such, job opportunities farther away are being discounted as they are less available than closer job opportunities (Parks, 2004; Shin, 2020).

According to Porter (1990), and Glaeser et al. (2004), agglomeration economies tend to attract a labor force with advanced skills. The combination of Philadelphia's urban revitalization projects, which focus on attracting innovative high-technology and global firms to the urban core, with the simultaneous emergence of high transit-induced agglomeration areas is more likely to attract highly educated human capital (Weaver, 2016; Wiig, 2019). As a result, low-skilled workers lack job opportunities, while high-skilled workers are concentrated in areas with agglomeration economies (Table 3). Accordingly, we expect a white-collar sector, knowledge-based industries (51-55), to show some form of clustering in high transit-induced agglomeration areas. On the other hand, we expect retail (45) and accommodation and food (71) sectors to be underrepresented in those high transit-induced agglomeration areas (Table 3).

In Table 3 below, we describe our selected variables, provide some summary statistics and data sources of the variables. First, we use effective densities, as defined above in Equation 2 as an important indicator for transit-induced agglomeration. As seen in Table 2, effective densities vary extremely, ranging from as low as 5 to over 700,000, with a mean of 7,400. In addition, the distribution of effective densities is heavily skewed to the right (Table 2). To better control for this large variation and to avoid problems of heteroscedasticity, we log-transformed effective densities in all econometric models (Chatterjee and Hadi, 2006).

A second group of variables are the built environment variables. Primarily, these variables measure Euclidean distances from each block group center to the CBD, to highway entries, to the international airport, and to universities. Our average Census block group is 12.23 miles from the CBD, 4.28 miles from the next highway entrance, 16.08 miles from the airport, and 3.56 miles from the next university (Table 2). In addition, we measure the percentages of commercial lands per block group to account for Philadelphia's revitalization efforts. These efforts focused on converting old industrial sites to commercial land uses to attract more service-oriented businesses and corporations (Wiig, 2019). We expect to find higher concentrations of service sector jobs in industries like knowledge-based industries (51-55), retail trade (44-45), and accommodation and food services (72) in these commercial zones (Table 3). The percentage of the commercial land use variable is only added to the econometric models which use industry-specific LQs as a dependent variable.

Next, we include some demographic variables (listed in Table 2) to account for variations in employment opportunities for different labor force groups. Specifically, we expect to find clusters of high-skilled jobs in and around neighborhoods where a large share of the population has bachelor's or advanced degrees. On the other hand, we expect to find low-skilled jobs to be concentrated in Census block groups with higher rates of racial and ethnic minorities and poverty (Table 3).

Finally, for an analysis on the first two econometric models - one with LQs for low-skilled employment and the other with LQs for high-skilled employment, we expect that areas with larger shares of blue-collar sectors, such as manufacturing (31-33) and construction (23) are likely to have higher shares of low-skilled jobs, whereas areas with white-collar sectors, such as healthcare (62), education (61), and knowledge-based firms (51-55), tend to have larger clusters of high-skilled jobs. For these two specific models, we defined two industry-mix variables, namely, percentages of blue-collar and white-collar workers.

Table 2: Summary of variables

Variable	**Description**	**Mean (Std. Dev.)**	**Range**
Employment (LQ)			
Low-skilled*	Ratio of a percent of skill- and industry-specific jobs in a block group to the percent in the metro region. LQ >1: overrepresented, LQ <1: underrepresented.	1.17 (0.32)	0 ~2.83
High-skilled*		0.82 (0.31)	0~2.85
Knowledge*		0.56 (0.76)	0 ~4.77
Retail*		1.14 (1.59)	0 ~9.93
Accommodation & Food*		1.2 (1.81)	0 ~13.33
Agglomeration			
Effective Density (ED)*ˆ	Job density in a block group and number of jobs in its neighbored block groups discounted by transit travel time.	7,409 (26,626)	5 ~703,311
Built Environment (BE)			
CBD'	Mile distance from a block group to the CBD.	12.23 (9.63)	0.09 ~48.7
Airport"	Mile distance from a block group to the international airport.	16.08 (9.34)	1.5 ~50.3
Highway"	Mile distance from a block group to highway entries.	4.28 (4.52)	0.03 ~30.7
University'	Mile distance from a block group to universities.	3.56 (3.54)	0.01 ~28.15
Commercial zone"	Percent of commercial land uses.	5.48 (7.05)	0 ~61.03
Demographics			
Bachelor$^*_*$	Percent of residents with a bachelor's or higher degrees.	35.6 (23.32)	0 ~100
Black$^*_*$	Percent of Black American residents.	26.44 (33.11)	0 ~100
Hispanic$^*_*$	Percent of Hispanic American residents.	9.06 (15.22)	0 ~97.07
Poverty$^*_*$	Percent of residents with poverty status.	15.44 (16.04)	0 ~100
Industry Mix			
Blue-collar*	Percent of industry jobs with mainly blue-collar workers.	39.6 (26.8)	0 ~100
White-collar*	Percent of industry jobs with mainly white-collar workers.	48.8 (28.8)	0 ~100
Data source: *LEHD, ˆGTFS, 'PennDOT GIS, "DVRPC GIS, $^*_*$ACS			

Table 3: Expected signs of the marginal effects on LQ

	Low-skilled	**High-skilled**	**Knowledge**	**Retail**	**Accommodation & Food**
Effective Density	−	+	+	-	-
CBD	+	−	−	+	+
Airport	−	+	+	−	−
Highway	−	+	+	−	−
University	+	−	−	+	+
Commercial zone			+	+	+
Bachelor	−	+	+	−	−
Black	+	−	−	+	+
Hispanic	+	−	−	+	+
Poverty	+	−	−	+	+
Blue-collar	+				
White-collar		+			

5.2 Econometric models

There is ample literature focusing on the fact that employment is not randomly distributed across space. As Ellison and Glaeser (1997), McCann et al. (2001), and Mansour (2017) have pointed out, spatial concentrations of specific types of jobs lead to spatial dependence, and in our case, to spatial dependencies of our dependent variables, the employment LQs. Glaeser et al. (1992), McCann et al. (2001), and Fracasso and Vittucci Marzetti (2018) emphasize that sectoral businesses and jobs tend to concentrate in an area in order to take advantage of sector-specific external economies. In addition, McCann and Shefer (2004), and Yu et al. (2018) argue that flows of information and innovative ideas spill over to adjacent areas creating spatial dependencies. Liu (2011) and Liu and van Holm (2019) further suggest that concentrations of blue-collar industries inevitably lead to low-skilled job clusters. As suggested by the relevant literature, we expect our dependent variables, the skill- and sector-specific LQs, to show significant signs of spatial dependence. We apply Moran's I tests to explore the potential presence of spatial autocorrelation of Location Quotients as defined above and the residuals of the individual Ordinary Least Square (OLS) models (Anselin, 1988; LeSage and Pace, 2009). According to the Moran's I test results, we conclude that all dependent variables, the LQs, and the residuals from the OLS models are spatially correlated as we expected (p-values < 0.001). As a direct result of the presence of spatial dependence, the OLS estimators would be inconsistent and/or inefficient. Thus, spatial econometric models will be given preference to address the present spatial interactions. In addition, we can distinguish spatial spillover effects from direct effects (LeSage and Pace, 2009). Direct effects refer to the effects of an explanatory variable on a dependent variable in one area from its own area, while spillover effects are the effects derived from neighbored areas (Anselin, 1988).

The choice of the appropriate weight matrix, W, is paramount in spatial econometric analysis (LeSage and Pace, 2009). We chose a queen contiguity weight matrix, as indicated in (Eq. 3) below, over a set of k-nearest neighbor weight matrices (k = 4 ˜ 8) based on AIC and BIC goodness of fit criteria (Table 4). For instance, for the model with the high-skilled LQ as the dependent variable, we get significantly smaller AIC (403.6) and BIC (517.5) when using a queen contiguity matrix as compared with the 7-nearest neighbor matrix (AIC: 413.6, BIC: 527.5). However, the difference is negligible in the low-skilled LQ model with an AIC of 799.95 and a BIC of 913.8 when using a queen contiguity matrix as compared to an AIC of 799.2 and a BIC of 913.1 for the 7-nearest neighbor matrix. Burnham and Anderson (2004) argue that a goodness of fit is only significantly different between models when the difference in AIC and BIC values is greater than 2 units. Using a queen contiguity matrix is also preferred over applying an inverse distance matrix. Table 4 below indicates that the model for high-skilled LQ has significantly lower AIC (403.6) and BIC (517.5) for the queen contiguity matrix variant than with an inverse distance matrix (AIC: 409.3, BIC: 523.2). In addition to an AIC and BIC comparison, we also argue on theoretical ground that the observed spatial autocorrelation is local in nature and only neighboring areas are spatially dependent on each other (Halleck Vega and Elhorst, 2015). From Table 4 we conclude that the queen contiguity matrix is more suitable for our spatial econometric analysis than k-nearest neighbor and inverse distance weight matrices.

$W_{ij} = 1$ if i and j are contiguous, $W_{ij} = 0$ if i and j are not contiguous or i = j

$$\sum_{j=1}^{n} \frac{1}{n} W_{ij} = 1, i = 1, 2, ..., n \tag{3}$$

Table 4: Expected signs of the marginal effects on LQ

		Queen	k-nearest					Inverse distance
			k = 4	k = 5	k = 6	k = 7	k = 8	
Low-skilled LQ	AIC	799.95	835.2	827.1	803.2	799.2	803.3	800.8
	BIC	913.8	949.1	941	917	913.1	917.2	914.7
High-skilled LQ	AIC	403.6	413.1	411.2	419.7	413.6	415.1	409.3
	BIC	517.5	526.96	525.1	533.6	527.5	529.6	523.2

In the second step, we also consider spatial spillover effects of some selected explanatory variables. Following the literature on agglomeration economies, we expect effective density (transit-induced agglomeration effects) expressed in (Eq. 2) to show significant signs of its spillover effects on job opportunities. Venables (2007) argues, for instance, that public transit improvements generate positive externalities between firms and industries by reducing commuting costs and raising wages, two of the forces explaining transit-induced agglomeration.

Agglomeration economies (ED_i) influence employment patterns (LQ_i) in the neighbored areas (Ellison and Glaeser, 1997; McCann et al., 2001). On theoretical grounds, we chose a Spatial Durbin Error Model (SDEM), which includes a spatially lagged X-variable. Specifically, we propose the use of the Spatial Durbin Error Model (SDEM), see Equation 4 below, which includes a spatial lag of ED_i and a spatial lag of $\sum_k X_{k,i}$ as identified by the W_{ij} matrix. In addition, we reject the use of the Spatial Durbin Model (SDM) on theoretical grounds, as the spatial spillover effects are local in nature and do not spread across the entire study area, a critical assumption of the SDM model (LeSage and Pace, 2009; LeSage, 2014). We further reject the use of the more restricted Spatial Lag of X model based on a Likelihood Ratio (LR) test. The spatial coefficient λ in the error term (see Equation 4) is statistically significant supporting our choice of the SDEM model.

$$LQ_{e,i} = \alpha + \beta \ln ED_i + \gamma BE_i + \delta \sum_k X_{k,i} + W_{ij}(\ln ED_i \theta + \sum_k X_{k,i} \zeta) + u_i, u_i = \lambda W_{ij} u_i + \varepsilon_i \tag{4}$$

Our final form of the SDEM model, as indicated in Equation 4, includes effective density (ED), a set of built environment variables (BE) including a distance to CBD, the airport, highways, and universities, and a percentage of commercial lands. The term $\sum_k X_{k,i}$ contains a set of control variables (X), including demographic characteristics (i.e., Bachelor's degree, Black, Hispanic, and Poverty) and two industry mix variables, (i.e., percentages of Blue-collar and White-collar jobs per Census block group). The spatial lags of the effective density (ED_i), the demographic characteristics, and the two industry-mix variables are included in the last expression, where W_{ij} is the spatial weight matrix. To increase the efficiency of the estimated parameters, the SDEM model uses a spatial autoregressive specification for the disturbances (u) which allows for global diffusion of shocks. However, there is no spatial lag of any of the built environment variables (BE), as physical characteristics of a block group are unique features and as such do not affect neighboring block groups (Eq. 4, Halleck Vega and Elhorst, 2015).

6 Results and discussion

We list all empirical results from the SDEM models in **Tables 5 − 7** below. Overall, the signs of the transit-induced agglomeration effects (ED_i) on low- and high-skilled jobs, i.e., $LQ_{\text{low-skilled}}$ and $LQ_{\text{high-skilled}}$, conform to prior expectations (Table 3 and 5). We find that transit-induced agglomeration negatively impacts low-skilled jobs and positively impacts high-skilled jobs. In other words, attracting multinational and high-tech businesses around transit stations undermines job opportunities for workers without specialized skill sets or higher educational levels, while favoring jobs with requirements that require a high-level of training and education. These findings confirm Wiig (2019) research, in that Philadelphia's revitalization projects, while stimulating agglomeration economies and increasing effective densities, led to a concentration of high-skilled jobs around transit stops at the expense of low-skilled jobs. Somewhat more mixed are our findings when taking a closer look at the three selected industry sectors (Table 6 and 7). The effects of agglomeration measured as effective density, are consistent with the presumed expectations (Table 3) for knowledge and retail industries as a total effect on knowledge jobs is positive while effective density brings a negative total effect on retail jobs. Our results, however, contradict prior expectations as the positive total effect indicates that accommodation and food industry jobs cluster in areas with agglomeration economies and strong transit access.

Now, looking at the results in Table 5 in greater detail, the direct and spillover impacts of agglomeration on low-skilled jobs have opposite signs. As expected, we find that effective density negatively correlates with low-skilled employment ($\widehat{\beta}$ = -0.032), while exhibiting a positive spillover effect ($\widehat{\theta}$ = 0.022) from neighboring Census block groups. These results indicate that low-skilled jobs are underrepresented in an area with agglomeration economies with the presence of a well-developed transit system. High-skilled jobs, on the other hand, cluster in high transit-induced agglomeration areas as indicated by a positive direct effect ($\widehat{\beta} = 0.018$). This result is consistent with our initial hypotheses and a direct result of Philadelphia's revitalization efforts. The city government has strived to revitalize inner-city deindustrialized sites since early 1990 (Weaver, 2016). It provided global high-tech and knowledge-based corporations incentives such as infrastructure investment, tax-breaks, and autonomous-governance in an effort to attract international corporations and to integrate Philadelphia into the global economy. These revitalized zones exhibit vibrant activities and robust transit accessibilities, which provides an ample number of jobs for a labor force with an advanced skill set rather than for low-skilled workers (Weaver, 2016; Wiig, 2019).

We further explain the positive spillover effects of effective density on the concentration of low-skilled employment ($\widehat{\theta} = 0.022$) from neighboring Census block groups. The recent revitalization projects, such as empowerment zones (EZ) or incentive zones, took place only in selective areas within selected neighborhoods which were deprived of economic opportunities. These specifically targeted zones have the tendency to create a patchwork of commercial enclaves throughout the metro area. As Wiig (2019) points out, most financial investments in infrastructure, including public transit improvements, were concentrated in EZ, often leaving neighboring economically disadvantage areas in further decline. Needless to say, the areas neighboring EZ often lack resources to attract businesses and to create new jobs. In summary, we conclude that the overrepresentation of low-skilled jobs in Census block groups adjacent to block groups exhibiting agglomeration economies are not a direct result of growing opportunities for low-skilled workers. Rather, the declining environment negates the creation of high-skilled jobs. A positive finding is that a large number of low-skilled jobs are in a close distance to high agglomeration areas with the potential to grow.

Proximity to the CBD (Central Business District) matters for both low-skilled as well as high-skilled jobs. As indicated in **Table 5**, the LQ_i for low-skilled jobs increases by 0.008 for each mile closer to the CBD, while the LQ_i for high-skilled jobs decreases by 0.010 for each mile further from the CBD. The results reflect an urban structure where jobs for the disadvantaged group of the population are concentrated in the inner-city, while the suburbs attract larger numbers of the regional human capital (Korb, 2011). At first, this finding seems to conflict with the results of the transit-induced agglomeration impacts on low- and high-skilled jobs, as the CBD is the major agglomeration center with good transit infrastructure. Figure 5 identifies clusters of low-skilled jobs (High-High) near the CBD, while low-skilled jobs are underrepresented (Low-High) in most of the remaining metro area and in the suburbs which are well connected with the city by public transit. On the contrary, Figure 4, shows high-skilled jobs are decidedly concentrated (High-High) in both the CBD and the immediate suburban areas.

Table 5: Effects of Transit-induced Agglomeration on Low- and High-Skilled Jobs (SDEM Estimators)

	Low-skilled LQ						**High-skilled LQ**					
	Direct		Spillover		Total		Direct		Spillover		Total	
	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value
Agglomeration												
Effective density	**-0.032**	<0.001	**0.022**	0.046	-0.01	0.2	**0.018**	0.02	-0.009	0.41	0.009	0.22
Built Environment												
CBD					**-0.008**	0.001					**0.01**	<0.001
Airport					0.0002	0.88					-0.003	0.11
Highway					0.0021	0.35					-0.003	0.21
University					**0.009**	0.001					**-0.01**	0.001
Demographics												
Bachelor	**-0.002**	0.001	**-0.002**	0.005	**-0.003**	<0.001	**0.002**	0.001	**0.003**	<0.001	**0.004**	<0.001
Black	0.001	0.05	**0.001**	0.039	**0.002**	<0.001	**-0.002**	<0.001	-0.001	0.09	**-0.003**	<0.001
Hispanic	**0.002**	0.024	0.0009	0.32	**0.002**	<0.001	**-0.001**	0.049	0.00007	0.93	-0.001	0.075
Poverty	-0.0002	0.63	0.0005	0.56	0.0003	0.75	0.0002	0.58	0.0007	0.42	0.001	0.26
Industry Mix												
Blue-collar	**0.003**	<0.001	-0.0005	0.33	**0.003**	<0.001						
White-collar							**0.003**	<0.001	0.0001	0.81	**0.003**	<0.001
λ	**0.12**	<0.001					**0.16**	<0.001				
Constant	**0.23**	<0.001					**0.48**	<0.001				
N = 2,963	Wald: 14.4 (p-value: <0.001), LR: 13.6 (p-value: <0.001)						Wald: 28.8 (p-value: <0.001), LR: 26 (p-value: <0.001)					
AIC	799.95						403.64					
BIC	913.83						517.53					

Bolded coefficients are statistically significant with p-value <0.05.

High-skilled jobs, i.e. $LQ_{\text{high-skilled}}$, correlate positively with proximity to universities and negatively with low-skilled job densities, i.e. $LQ_{\text{low-skilled}}$ (Table 5). Corporations and organizations that require advanced skills have incentives to locate near higher educational institutions to collaborate with the academics in Research and Development (R&D) and exchange sophisticated technologies and innovative knowledge (Porter, 1990). As expected, low-skilled jobs cluster in areas with large shares of blue-collar industries, and block groups with high percentages of white-collar industries also have high percentages of high-skilled jobs.

The spatial econometric model results presented in Table 6 and 7 show the impacts of transit-induced agglomeration (ED_i) on job opportunities (LQ_{industry}) in selected industry sectors, including knowledge-based industries (51-55[2]), retail trade (44-45), and accommodation and food services (72). As expected, effective density (ED) has a positive total effect ($\widehat{\beta + \theta} = 0.072$) on the location quotients of knowledge-based jobs, where we define the knowledge sector as information (51), finance and insurance (52), real estate rental and leasing (53), professional, scientific and technical services (54), and management of companies and enterprises (55). Our empirical findings of concentrations of knowledge-based industry jobs in block groups with vibrant economic activities and strong public transit connectivity reaffirm prior expectations. These findings remain consistent with the results of the positive impacts of transit-induced agglomeration on high-skilled jobs. The incentives of market-oriented economic development initiatives, such as federally-funded empowerment zones (EZ) and incentive zones, were mostly provided to innovative knowledge-based and high-technology multinational firms (Weaver, 2016). We also confirm (McCann et al., 2001) that a more educated labor force can be found in block groups with high concentrations of knowledge-based jobs. This supports our hypothesis that knowledge-based firms have an incentive to be close to high-skilled labor pools.

Table 6: Effects of Transit-induced Agglomeration on Knowledge Industry Jobs (SDEM Estimators)

	Knowledge LQ					
	Direct		Spillover		Total	
	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value
Agglomeration						
Effective density	**-0.051**	0.02	**0.12**	<0.001	**0.072**	0.001
Built Environment						
CBD					**0.017**	0.007
Airport					0.0007	0.88
Highway					**-0.016**	0.008
University					-0.002	0.8
Commercial zone					**0.006**	0.008
Demographics						
Bachelor	**0.003**	0.005	**0.007**	<0.001	**0.01**	<0.001
Black	0.0008	0.5	-0.001	0.37	-0.0005	0.58
Hispanic	0.002	0.21	-0.0008	0.72	0.001	0.48
Poverty	-0.0001	0.93	-0.003	0.2	-0.003	0.18
λ	**0.18**	<0.001				
Constant	**-0.5**	0.012				
N = 2,963	Wald: 38.4 (p-value: <0.001), LR: 37.6 (p-value: <0.001)					
AIC	6,327.30					
BIC	6,435.50					

Bolded coefficients are statistically significant with p-value <0.05.

Next, we find mixed results when breaking down total effects into direct effects and spillover effects in relation to the impacts of agglomeration economies on knowledge-based industries (Table 6). The positive spillover effects of public transit-induced agglomeration on knowledge-based jobs implies an important function of agglomeration economies. Knowledge-based businesses thrive by learning new ideas and cutting-edge technologies from other knowledge-based companies. The result indicates which type of firms take advantage

[2]Two-digits North American Industry Classification System (NAICS) code.

of better access to valuable information and ideas in the presence of agglomeration economies within close distances (Glaeser et al., 2004; Chatman and Noland, 2014).

On the other hand, our estimated coefficient of the direct effect of transit-induced agglomeration on knowledge-based sector jobs is negative ($\widehat{\beta}$ = -0.051). Until the 1980s, professional jobs were mostly created in the suburban areas (Korb, 2011). A large number of knowledge-based firms, e.g., finance and insurance (52) and real estate (53), may still be located in these areas and as such they are remote from the economic centers as well as public transit infrastructure. Based on the LEHD data, the knowledge-based sectors (51-55) comprise 19% of total employment in the city, whereas the figure is 22% in the suburbs. This implies that a large number of knowledge-based industry jobs are located in block groups with a lower influence of agglomeration economies and public transit access. Moreover, as shown in Table 6, the industry jobs are more likely to concentrate in areas farther away from the CBD and closer to highways. However, the magnitude of positive spillover effect ($\widehat{\theta}$ = 0.120) is more than twice the estimated negative direct effect ($\widehat{\beta}$= -0.050). Our result suggests that the present information spillover effects (McCann et al., 2001) of agglomeration economies are stronger than existing suburbanization effects (Korb, 2011).

Overall, transit-induced agglomeration (ED_i)has a negative impact on retail jobs as shown by a total effect of -0.14. The sector's major difference from the knowledge-based sector is its disproportionately large share of low-skilled employees. Our finding confirms our hypothesis that block groups with transit-induced agglomeration economies have fewer low-skilled jobs than the higher-skilled professional jobs. As mentioned above, recent revitalization efforts funneled incentives, such as tax breaks and self-governance to firms with advanced talents (Wiig, 2019). Consequently, job opportunities in other industries with mostly low-skilled workers may decline in those areas compared to knowledge-based firms. This conclusion is further supported by the estimated direct effect of college-educated residents ($\widehat{\delta}$ = -0.008) which negatively correlates with the concentration of retail jobs.

With respect to the concentration of accommodation and food services jobs, our estimated coefficient for public transit-induced agglomeration economies as measured by the effective density shows a positive total effect of 0.210. Although it is a sector with many low-skilled employees, it is an export-based industry that serves international professionals who attend business meetings and conferences related to innovative high-tech and knowledge-based industries. According to the labor market polarization theory (Lindley and Machin, 2014), low-skilled jobs providing essential services for the more educated population also grow rapidly along with high-skilled jobs in regions with agglomeration economies. The City of Philadelphia has heavily invested in tourism and attracted hospitality businesses into the EZ since the early 1990s during Ed Rendell's mayorship to raise the global standing of the city (Weaver, 2016). Domestic and international professionals stay in hotels and dine in gourmet restaurants during business trips or attend conference meetings which explains the locational choice to stay where they find abundant public transit choices and strong agglomeration economies.

A noteworthy though expected result is that increasing the availability of commercial land positively impacts the LQs of all three service sectors: knowledge-based services (51-55), retail trade (44-45), and accommodation and food services (72). This finding is supported by Philadelphia's urban history where the conversion of vacant industrial land into commercial uses contributed to the creation of both low- and high-skilled service jobs (Johnson et al., 2002; Weaver, 2016). Depending on the type of service activity, these effects can be stronger or smaller. Increasing the size of the commercial zone has strong positive effects for retail trade ($\widehat{\delta}$ = 0.05) and accommodation and food services ($\widehat{\delta}$ = 0.03) sectors, with significantly smaller effect for the knowledge-based service sector ($\widehat{\delta}$ = 0.006). Retail and accommodation and food service industries seem to be more sensitive to the actual size of the commercial land share because grocery stores, shopping malls, and hotels require relatively more space per employee than firms with office space requirements.

Table 7: Effects of Transit-induced Agglomeration on Retail and Accommodation & Foods Industry Jobs (SDEM Estimators)

	Retail LQ						**Accommodation & Foods LQ**					
	Direct		Spillover		Total		Direct		Spillover		Total	
	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value	Coeff.	P-value
Agglomeration												
Effective density	-0.015	0.76	**-0.13**	0.046	**-0.14**	0.002	-0.031	0.57	**0.24**	<0.001	**0.21**	<0.001
Built Environment												
CBD					**-0.026**	0.049					-0.02	0.2
Airport					0.005	0.88					0.004	0.72
Highway					**0.025**	0.04					0.008	0.55
University					-0.02	0.23					**0.039**	0.03
Commercial zone					**0.054**	<0.001					**0.03**	<0.001
Demographics												
Bachelor	**-0.008**	0.005	-0.003	0.31	**-0.01**	<0.001	0.0009	0.77	0.0001	0.98	0.001	0.72
Black	-0.003	0.23	0.001	0.74	-0.002	0.32	-0.002	0.55	-0.006	0.07	**-0.008**	<0.001
Hispanic	-0.002	0.5	0.002	0.73	-0.0007	0.84	0.003	0.53	**-0.013**	0.018	**-0.011**	0.01
Poverty	-0.0005	0.85	-0.007	0.17	-0.008	0.13	-0.003	0.54	0.003	0.6	<0.001	0.998
λ	**0.14**	<0.001					**0.13**	<0.001				
Constant	**2.69**	<0.001					-0.36	0.45				
N = 2,963	Wald: 22.5 (p-value: <0.001), LR: 21.2 (p-value: <0.001)						Wald: 18.7 (p-value: <0.001), LR: 17.8 (p-value: <0.001)					
AIC	10,971.20						11,767.40					
BIC	11,079						11,875.20					

Bolded coefficients are statistically significant with p-value <0.05.

Regenerating declining neighborhoods, as is the case in Philadelphia, is in fact crucial to reviving city life and creating economic opportunities. However, what concerns us is the unequal access to some of the benefits brought to the city by means of agglomeration economies. Our analysis finds that the low-skilled labor force is often left out, while the high-skilled labor force enjoys the fruits of vibrant economic activities and superior public transit accessibility. Agglomeration economies should improve not only efficiency (McCann et al., 2001), but also equity (Lindley and Machin, 2014) to offer opportunities to all groups of society. Furthermore, public transit is an essential commuting mode for socially and economically disadvantaged groups due to the financial burden of car ownership (Glaeser et al., 2008; Tomer, 2011). Thus, low-skilled employees may face a significant barrier accessing jobs when they are alienated from high transit-induced agglomeration areas.

The City of Philadelphia has endorsed the private sector in the revitalized zones since the 1990s with self-governance rights, which, as Weaver (2016) and Wiig (2019) point out, resulted in funneling investments to advanced talents at the cost of low-skilled jobs. The public sector should extend interventions to increase opportunities for the disadvantaged labor force. For example, the government could subsidize businesses near transit stops, which have a large share of low-skilled workers with low-interest loans or cost-sharing of operating and capital expenditures. In addition, it could increase density near transit stops to provide more spaces for small businesses through up-zoning. Transportation planners should take the high demand for transit for the low-skilled labor force into account when planning, creating, and extending transit routes. Workforce development programs should target low-skilled workers with teaching a diverse range of skill sets to maximize their job prospects. In particular, the programs should focus on skills in industries with growing demand. In sum, holistic and coordinated planning and public policies can enhance access to economic opportunities for the low-skilled labor force.

7 Conclusion

This paper focuses on the effects of agglomeration associated with transit on job opportunities for low- and high-skilled employees. Low-skilled jobs tend to be underrepresented in areas with agglomeration economies and a high density of transit facilities. On the other hand, high-skilled jobs are more likely to concentrate in those places rather than in the entire metro region. Philadelphia's officials prioritized the recruitment of global firms and information and high-tech businesses in the revitalization zones (Weaver, 2016; Wiig, 2019). The weak presence of low-skilled jobs in a flourishing economic center with strong transit connectivity could undermine the disadvantaged workers' job accessibility. The spillover effect of transit-induced agglomeration on low-skilled jobs in neighboring areas is positive, implying that the areas outside of the patched revitalization zones are in decline, which has a relatively high share of low-skilled jobs (Wiig, 2019). However, this also indicates that many low-skilled jobs are readily accessible to high agglomeration areas.

We witnessed a tendency of knowledge industry clustering in high transit-induced agglomeration areas, which is consistent with the result of the positive correlation between the agglomeration and high-skilled employment and the favoritism for high-technology and knowledge-based businesses in revitalized zones. On the other hand, retail jobs have a negative relationship with the agglomeration associated with transit. It also parallels with the result that low-skilled jobs are underrepresented in high agglomeration areas. Accommodation and food service jobs are concentrated in locations with the high agglomeration regions even though it has a large percentage of low-skilled workers. The hospitality industry provides services to many workers with advanced skills. Thus, the businesses have an incentive to be located near high-skilled jobs (Lindley and Machin, 2014). Moreover, the city government promoted tourism, which directly affected growth of the hospitality and restaurant businesses (Weaver, 2016).

Policymakers should consider economic policy, land use and transportation planning, and workforce development programs to improve equity. Local governments could more actively engage in supporting low-skilled employment. For instance, it could finance low-interest loans or subsidize operating costs to small businesses with a large share of low-wage/skilled employees near transit stops. Moreover, up-zoning could provide more spaces for small businesses and transit routes should be extended to districts where low-skilled workers have high demand transit needs. Finally, workforce development programs could help the labor force to obtain diversified skills, especially skill sets with growing demands. Such training would help workers maximize their opportunities.

With this paper, we attempt to contribute to the studies on public transit-induced agglomeration economies. Our study is one of the few studies that specifically focuses on the low-income labor force (Lindley and Machin, 2014). In addition, previous studies mainly looked at the effects of public transit infrastructure on agglomeration economies (Chatman and Noland, 2014; Credit, 2019). Moving one step further, we investigated the impact of transit-associated agglomeration on low-skilled employment. However, this study also has limitations. Currently, we do not have data of labor forces' transit demand by skill level. A demand analysis on the low-skilled labor force would allow us to examine the gap between the demand and access to jobs by transit for this low-skilled labor force. Moreover, availability of panel data from pre-revitalization could allow us to investigate a direct effect of the urban revitalization projects on the labor market in Philadelphia.

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