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Exploring changes in the spatial distribution of the low-to-moderate income group using transit smart card data

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ABSTRACT

Property booms have caused residential spatial distribution changes in many metropolitan areas. To understand the impact of surging housing prices on the low-to-moderate income group, this study uses transit smart card data to explore whether and to what extent increasing housing affordability pressure impacts the pattern of residential spatial distribution. This analysis is based on the facts that most public transit commuters are in the low-to-moderate income group and that transit smart cards continuously record individual spatial choice behaviors. Compared with conventional approaches using census data or survey data, our approach can more quickly detect residential changes. Experimental results indicated that most low-to-moderate income dwellers lived in low-housing-cost areas with high accessibility to public transportation. Three relocation patterns were discovered based on significant changes in residential spatial distribution. The overall pattern is to move from the inner city to suburban areas or to the urban periphery, where housing costs are much lower. Specifically, these commuters moved along traffic corridors (metro lines), which indicates that their residential choices were constrained by employment locations and public transport facilities. Finally, these commuters presented a jumping relocation pattern along metro lines due to the search for low-rent housing. Our findings provide some insights into urban dynamics, as well as urban and housing policies.

1. Introduction

In recent years, many global metropolitan cities, such as New York, London and Paris, have undergone “the Great Inversion”, in which luxurious housing, high-paid jobs and affluent people return to city centers (Ehrenhalt, 2012). This has caused a sharp increase in housing prices and rents, making the city center unaffordable for many people at average incomes or below-average incomes (Mcdermott, 2014). This is also a prominent phenomenon in some large Chinese cities. In 2015, the average price of commercial houses increased more than 8% in Beijing, nearly 20% in Shanghai and approximately 40% in Shenzhen (China Appraisal Association, 2016). Rents also underwent a dramatic increase along with the rising housing prices. In London, the median rent represents more than 50% of median local full-time earnings (Liam, 2011), and the proportion is similar in most major Chinese cities.[1] The dramatic increase in housing costs makes housing increasingly unaffordable for some low-to-moderate income residents, especially tenants. This has spurred housing affordability issues and become a top social concern (Yang & Chen, 2014). These people either escaped from metropolitan cities or moved to low-housing-cost areas, trigging urban residential redistribution.

Residential spatial distribution has been investigated based on different socially meaningful traits, such as race/ethnicity (Johnston, Poulsen, & Forrest, 2007; Massey, 1990), income (Ades, Apparicio, & Séguin, 2012; Rey & Folch, 2011), education (Domina, 2006), and occupation (Blau, Simpson, & Anderson, 1998; Cohen & Huffman, 2003). In recent years, accompanying rising inequality in the economic level, income is increasingly more influential on the choice of residential spaces in Western countries (Bischoff & Reardon, 2014) and in China (Khan & Riskin, 2001). Therefore, residential spatial distribution of the low-income group has received extensive attention (Li & Wu, 2013). There is evidence that housing affordability is a key factor that influences the residential choices (Wang, Wang, & Wu, 2010) and relocation behaviors of economically disadvantaged groups (Howell & Timberlake, 2014). It also potentially drives social inequalities by escalating housing costs in some countries (Baker, Bentley, Lester, & Beer,

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[1] http://news.sina.com.cn/o/2017-07-21/doc-ifyihrwk1687123.shtml

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2016; Yang & Chen, 2014).

Most existing studies have examined changes in residential distribution based on census data over a long period, such as years or decades (Cooke & Marchant, 2006; Liao & Wong, 2015). To the best of our knowledge, limited research has explored the short-term dynamics caused by surging housing affordability pressure due to the difficulty of acquiring data. These macro-demographic analyses based on census data were unable to reflect dynamic changes in a short time frame or in a certain period. Additionally, census data are at the sub-district or larger spatial scales, which may lead some spatial heterogeneities to be overlooked. Although traditional social survey data can be a complementary source to measure the change of residential spaces at finer spatial and temporal resolutions, the sample is usually relatively limited or only encompasses a small area given the time consuming and laborious drawbacks of questionnaires or interview surveys. Thus, there has been an inability to adequately describe the overall pattern of residential relocations. The influence of housing affordability on the low-to-moderate income population is immediate because most of this population are tenants, but traditional data and approaches are unable to continuously track the residential choice behaviors of this group. Therefore, alternative methods should be proposed to allow geographers to more quickly investigate short-term urban dynamics.

The recent developments of emerging geo-tagged data sources have provided opportunities to analyze spatial-temporal behavior at an individual level and better describe and understand dynamic urban space at a finer scale (Liu et al., 2015). These sources include mobile phone data (Gao, Liu, Wang, & Ma, 2013; Yue et al., 2017), floating car data (Scholz & Lu, 2014), smart card data (Gong et al., 2012, June), and social media check-in data (Yin, Soliman, Yin, & Wang, 2017). Among these spatial behavioral big data, transit smart card data record the day-to-day variability of individual travel patterns and can potentially detect their spatial-temporal regularities through continuous observation. Therefore, these data have been widely utilized to explore urban spatial dynamics in multiple dimensions, such as urban structures (Gong, Lin, & Duan, 2017), travel behaviors (Ma, Wu, Wang, Chen, & Liu, 2013) and job-housing relationships (Long & Thill, 2015). The data have revealed the ability to continuously track individual residential choice behaviors, and thus can be utilized to explore residential distribution changes at a finer spatial and temporal granularity. Regular transit commuters tend to be low-to-moderate income residents who exhibit the greatest incidence of housing stress (Long & Shen, 2015). According to the 6th Residents Travel Survey data of Shenzhen in 2016, more than 90% of public transit commuters in Shenzhen are from the lower-class group. A study in Beijing also revealed that residents who rely on public transportation tend to be economically underprivileged (Long, Liu, Zhou, & Chai, 2016). Compared with the high-income group, they are constrained by economic factors and are more vulnerable to the market environment.

This study explored how the residential spatial distribution of the low-to-moderate income group changed under increasing housing affordability pressure using individual-level transit smart card data from Shenzhen, China. To address this question, we first extracted the residences and workplaces of low-to-moderate income residents from transit smart card data, as described in Section 3. In Section 4, their residential spatial distribution was studied by identifying areas with significant concentrations. Finally, in Section 5, three types of relocation patterns were discovered based on changes in the residential spatial distribution from the one-year time-series dataset. This study makes the following contributions from the methodological, policy-oriented and theoretical perspectives. First, compared with traditional approaches, this study explores the residential spatial distribution changes for the low-to-moderate income population over a very short time frame by directly tracking individual residential relocation behaviors using public smart card data, which have greater timeliness and a finer spatial scale. Second, the results of this study provide insights into the urban dynamics related to residential spatial patterns under rising housing affordability pressure. These insights could help policy-makers review and evaluate their related land-use planning and housing policies, especially urban renewal policies. Third, our primary findings are complementary to Western urban development theory in a different national context in light of urban residential redistribution patterns.

2. Study area and data

The study area is Shenzhen, a city in southern China adjacent to Hong Kong. It was the first Special Economic Zone and is now well known for high-tech and innovative industries. Shenzhen is the youngest and the largest migrant city in China (Tao, Hui, Wong, & Chen, 2015). In 2015, approximately 68.8% of the total population was migrants (Shenzhen Municipal Statistics Bureau, 2016) with an average age of 32.5 years.[2] Accompanying rapid economic growth, housing prices and rents in Shenzhen significantly increased. Also in 2015, the average price of commercial housing increased approximately 40% and exceeded Beijing (8.10%), Shanghai (17.60%) and Guangzhou (0.88%), three first-tier metropolitan cities in China (China Appraisal Association, 2016). The surging housing costs might exceed the affordability of some low-to-moderate income residents and cause residential stress. Therefore, Shenzhen is a representative area for this study.

Shenzhen is divided into 491 TAZs (Traffic Analysis Zones) based on districts (Fig. 1). Compared with the sub-district and district, the TAZ has a finer spatial scale and is more suitable for urban research because it fits into administrative boundaries, considers road networks and retains the similarity of land-use type and economic and social properties. TAZs are used as the spatial unit in the study.

Public transit smart card data (including buses and subways) from January 2015 to December 2015 were utilized to explore the changes in residential distributions. When a cardholder uses his/her smartcard to pay for a transportation service, the terminal installed in the bus or subway station automatically generates the following information: unique card number, trade time, and card type (student and senior cards are discounted versus regular cards). The terminal and bus/subway information are obtained from a “line/station & equipment comparison table”. Bus GPS trajectory data record the bus number, time, longitude, latitude, direction and speed. Details for bus and subway trip data are shown in Tables 1 and 2, respectively.

To obtain complete origin-destination information for every trip, a station matching process is necessary. By cross-referencing the terminal ID and trading time, we can discover which bus passengers get on and at what location from the GPS data. Bus lines/stations can geocode and map every rider to the station. The subway station matching process is similar but easier, since it does not require matching GPS data.

There are approximately 4 million bus trips and more than 2 million subway trips each day (Fig. 2). The average daily ridership is approximately 3 million. More than half of passengers commute by bus, nearly 1/3 commute by subway, and the rest commute using both (Fig. 3).

3. Identifying residence and workplace

There is solid evidence that most individuals have a high degree of spatial-temporal regularity, that is, they have a significant probability of returning to a few highly frequented locations, which are generally found to be the residence and the workplace (Gonzalez, Hidalgo, & Barabasi, 2008; Schneider, Belik, Couronné, Smoreda, & González, 2013). In particular, people perform working-day activities in a “home-work-leisure (optional)-home” order. They commute to their workplace

[2] Shenzhen Municipal Government. “The 13th Five-Year Shenzhen population and social development plan” (2017). http://www.sz.gov.cn/zfgb/2017/gb987/201701/t20170111_5879219.htm#