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Tram Fare Removal and House Prices - A Case Study of Melbourne

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< Abstract >

This paper studies the impact of abolishing tram fares in the city center of Melbourne (CBD) on the real estate market. Since January 1, 2015, tram users have not had to pay tram fares within the designated free tram zone. It is found that real estate condominium buyers living within 100 meters from this zone pay prices which are 8.7% to 10.7% higher compared with similar purchasers in other areas since fares were abolished. This positive price impact is muted for the residents who live within the free tram zone. Additional controls for distance to the tram stops in the zone or distance to the local attraction with announced renovation plan do not affect the positive price change. When tested with a randomized date of fare removal, the level of price change is not statistically and economically significant.

Keyword : Real Estate Price, Public Transport, Transport Fare Removal, Transport Fare, Tram

I. Introduction

One of the most serious urban issues is congestion due to transport. While many countries have tried to curb the volume of traffic through pricing channels for road pricing or parking charges, it is quite common to face strong opposition from the public resulting in a failure to levy extra costs on transportation (Suryo et al., 2007; Shaller, 2010; De Borger and Proost, 2001). Another channel is through improvement of infrastructure and accessibility. Extant papers discuss the efficacy of enhanced accessibility to public transport and find that proximity to public transportation has a positive impact on house prices (Hu, 2017; Hou, 2017). Of course, not all the commuters or residents respond to transport improvements. Responsiveness varies by distance from the CBD area to the location of rider (Baum-Snow and Kahn, 2005) or is influenced by the location of a station, tram or bus stop (Hu, 2017). The house market is also affected by different levels of income (Hou, 2017; Adair et al., 2000). However, contrary to the positive response or capitalization suggested by the literature, a series of studies argues that transport policy can have a negative or unanticipated impact on the economy. Jackson and Owens (2011) find

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that the change of train schedules increased the rate of alcohol related crimes. Davis (2008) documents that in Mexico the policy that allowed days when only vehicles with odd or even numbered registrations could use the streets caused an increase in the number of vehicles. Other papers discuss how the enhancement of local/national transport systems lead to gentrification resulting in lower affordability for low-income families (Zheng and Kahn, 2013), or changes in borrowing behavior by rural villagers (Agarwal et al., 2018).

All the extant papers in the urban context are related to the variables explained by the commuting time and cost in distance as described in the classical bid-rent gradient model; the impact on the choice of transport; and the response in the real estate market (Coulson and Engle, 1984). However, the relationship between removal of transport costs and real estate price is barely studied1). To fill the gap in the empirical literature, this paper focuses on the response in real estate market when transportation cost is removed2). In contrast to the existing literature which focus on changes in gasoline prices for self-driving commuters (Coulson and Engle, 1984), this paper focuses on the removal of fares in public transport.

The local government of Melbourne decided to encourage people to use public transport by removing tram fares for trips within a designated inner-city free tram zone, from January 1, 2015. By using this event as a natural experiment with real estate condominium3) transaction data, this paper aims to find the impact of fare removal on the real estate market. To preview the results, the analysis finds that condominium prices in Melbourne do not change significantly within the free tram zone after the fare removal. However, the condominiums located within 100-meter buffer from the free tram zone show a significantly positive change in transaction price by 8.7% to 10.7%. Adding additional control variables, such as distance to the tram stop within the free tram zone or distance to the local attraction with announced renovation plan, for robustness test or confounding factor analysis does not change the tenor of the positive response. The significant response in the 100-meter buffer is attributable to the geographic location of condominiums that allows residents to walk to the free tram zone. Considering the geographic size of the free tram zone (2.84 square kilometer) and density of tram stop in the zone, it is likely that the residents living in the free tram zone do not receive extra utility *ex post*, whereas those who live near the boundary of the free tram zone enjoy higher utility by not paying the tram fare.

Falsification tests are conducted with an arbitrary fare removal date. The condominiums within 100-meter buffer do not respond to this arbitrary date. Additionally, time falsification simulation is conducted 1000 times by setting arbitrary dates between January 2010 and December 2013. The average coefficients of interest (i.e. interaction term of 100-meter buffer and post-treatment dummy) are statistically and economically insignificant.

This paper provides a twofold contribution to

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1) In the context of socio-economic impact and agents' behavior related with fare removal, a few cases of tare removal was introduced by a group of literature (Gabaldon-Estevan et al., 2019; Cats et al., 2017; Cats et al., 2014; Hess, 2017; Kębłowski, 2020; Boyd et al., 2003).

2) Voith (1997) shows the impact of transport policy and changes of demographic composition on the public transport ridership, which has a negative relationship with fares and more pronounced impact in longer term analysis. Wang, Li and Chen (2015) analyzed the price elasticity of demand from a survey conducted in Beijing. They show that the price elasticities are stronger in short trips (no longer than 5km) than in medium or long ones.

3) In this paper, the term 'unit' is used to describe strata titled residential properties (condo) in contrast to 'house' which means detached house.

the existing literature. First, it adds a new empirical analysis to the study of transportation and real estate prices in relation to transport fares whereas most previous literature focuses on the increase of transportation cost. Secondly, the impact of transport policy can attribute to the expansion of the CBD area, which in turn affects the price level of the expanded area. As Hilber (2017) argues, much of the literature investigated unintended redistribution and the effects of capitalization. According to the literature introduced in this paper, government aid, grants, and geographic incentive programs had unintended capitalization effects in the housing market, which adversely affected marginalized classes (Wyckoff, 1995; Hilber et al., 2011; Hanson, 2009). Thus, the response is expected to vary across heterogeneous classes and location.

The following sections will provide a brief introduction to the literature on the fare removal and the operation of the tram system and policy changes in Melbourne. Then the dataset and research methods are described, followed by the results of the analysis including the baseline model and the falsification model. The whole paper will be concluded in the last chapter.

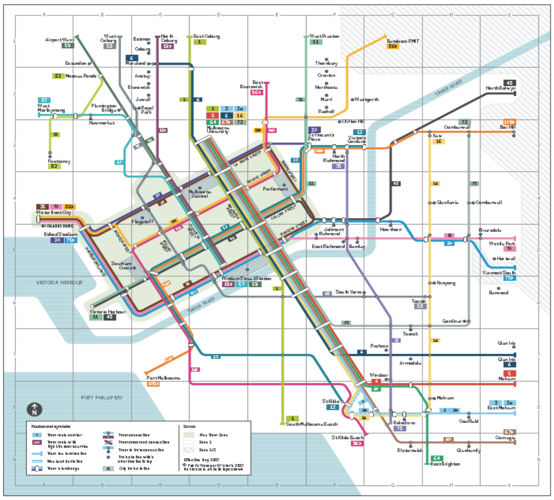
II. Literature Review

Even though it is not that common to find cities or municipalities with no fare of transport in the world, quite a few cities have already adopted the concept of fare-free public transport. Kębłowski (2020) introduces the conceptual framework of fare-free transport system and defines the difference between full fare-free public transport (FFPT) and partial FFPT. Full FFPT is defined as a system where the public transport system is provided for free to vast majority of users with least limited timeframe and has been implemented over a 12-month period, while the partial FFPT is not meeting the criteria listed above: implemented for a limited time or covers only a few lines of the public transport routes. The same paper also argues that there are lots of variation across countries in terms of FFPT. The concept of private transport with fare-free system, such as free shuttle buses owned by shopping centers to accommodate more shoppers to the shopping centers, is set aside for future study for the current paper. Volinski (2012) lists and analyzes the status quo of FFPT in the US and compares with the cases of other countries. Especially, the paper argues that the FFPT program can cause negative amenities to the related area when the issues of joyriding, rowdiness and overcrowding happen. So, it should be understood that the perception of free public transport system has both positive and negative results in the socio-economic context. As the classic theory from von Thünen argues, the bid-rent gradient has close relationship with the accessibility to the marketplaces, which in turn is linked to the transportation cost. When the cost of transport both in time and monetary measure is lower, the benefit of saving in time and money should be reflected in the real estate price in either rent or price. However, as Volinski (2012) and Hodge et al. (1994) mention, the implementation of free fare system can bring much more foot traffic to the subject area and cause troubles that would have negative impact in the designated area. Gabaldon-Estevan et al. (2019) discuss that the introduction of FFPT can deteriorate the quality of public transport and argue that some opponents against the FFPT were worried about the sustainability of the program and potential negative externality caused by the FFPT. So, it is evident that there are two contradicting factors that push up the bid-rent gradient and bring down the bid-rent gradient through the positive and negative amenities caused by the FFPT. Even though Hodge et al. (1994) is a relatively outdated paper at present, estimated increase of ridership by 25 percent to 50 percent after potential removal of fare clearly casts important signal about the negative impact. Albeit different across different countries under various circumstances, the change in ridership in Brown et al. (2003) confirms that a free shuttlebus service to a university increased bus ridership by 56 percent and decreased self-driving mode by 20 percent. However, Cats et al. (2014) and Cats et al. (2017) argue that the magnitude of modal shift from cars to public transport is quite limited at around 3 percent in the case of Tallinn located in Estonia. While the modal shift is lower than anticipated, it is found that the increase of ridership in the public transport increased 14 percent with more marked response in low-income class. So, considering heterogeneous circumstances across countries, it is not unusual to find different response from the transport policy implementation.

III. Tram fare removal in Melbourne

In Melbourne, Victoria, the public transport system is more than 100 years old. Since the first operation of electric trams in 1889[4], the tram service has been one of the major transport modes along with train and bus systems. Currently a total of 24 tram routes operate with more than 475 trams in the greater Melbourne area[5]. As <Figure 1> shows, tram operation covers most of the inner suburban area surrounding the CBD.

<Figure 1> Map of tram lines in Melbourne, Victoria



Note: This figure shows the map of tram lines operating in the greater Melbourne area. Source: Public Transport Victoria[6].

However, due to the increase in population and the escalating number of penalties levied on tourists who failed to pay the correct fare, because they did not understand the zonal fare structure, the Victorian Government decided to introduce a new system in 2014. This involved two major changes. The first was a change to the zonal fare system. Previously, the fare table was composed of three zonal fare classes: zone 1+zone 2, zone 2, and zone 1[7]. Accordingly, tram users paid the highest fare for rides covering zone 1 and zone 2, and the lowest fare for trips within zone 2, which covered suburban areas around Melbourne. However, this zonal fare system had a side effect. Riders who wanted

4) https://yarratrams.com.au/melbournes-tram-history

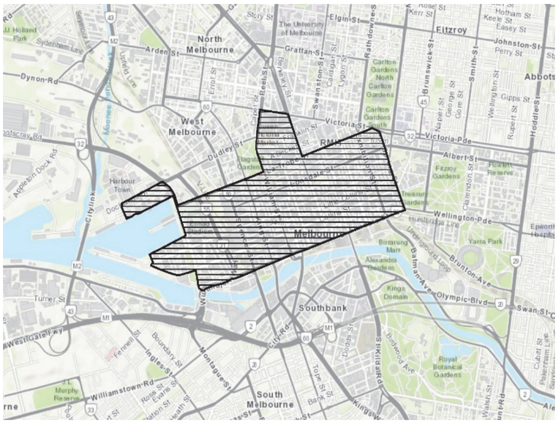
5) https://yarratrams.com.au/our-fleet-today

6) https://static.ptv.vic.gov.au/public-transport-victoria/1491350490/PTVH2153_TramNetworkMap_A3_L_March2017_v1_FA_LOCKED.pdf

7) Two hours of travel in zone 1 + zone 2 was $6.06; the fare for zone 1 was $3.58; and the fare for zone 2 was $2.48 in 2014 when tram users had a prepaid ticket called ‘myki card’.

to avoid the higher fare for trips covering both zone 1 and zone 2 often drove to the zone 1 area and parked their cars to make trips within zone 1. This brought congestion and problems of parking space[8]. As part of the changes, the local government introduced a combined single fare system in 2015 regardless of the length of trip. This way tram users paid a fare covering zone 1 or zone 1 + zone 2 but paid a discounted fare for trips within zone 2[9]. The other major change was the introduction of a free tram zone in the city center of Melbourne. Effective from January 1, 2015, tram fares were removed when tram riders travel within the designated free tram zone.

<Figure 2> Map of free tram zone



Note: This figure locates the free tram zone in Melbourne, Victoria. On January 1, 2015 the local government removed tram fares for trips within the shaded zone. Previously the fare for trips within this zone was AU$3.58.

As shown in Figure 2, the free tram zone covers Queen Victoria Market to Docklands, Spring Street and Federation Square. This is approximately 2,843 square meters with the longest horizontal and vertical distances 2.94km and 1.57km respectively[10]. Thus, tram users travelling within this zone could save $3.76 per ride with the new structure.

The anticipated benefit of tram fare removal is not purely the financial benefit to the tram riders. Since riders do not need to tap the prepaid tram cards when getting on or off, trams can move more quickly in this already congested area. Hou (2017) argues that willingness to pay for houses increase with easier accessibility. Thus, when commuters can enjoy shorter commuting times, it is expected that buyers will be willing to pay a premium on real estate. It is also known that the mode of commuting has a close relationship with commuters' wellbeing. Chng et al.(2016) find that car commuters show the lowest satisfaction level compared with users of public transport in London. Those who have better connectivity, in particular, show a higher level of satisfaction. The response in China was different from the results in London. There was no significant difference for commuters using public transport or cars (Zhu and Fan, 2018a). However, the same paper finds that commuters who use an employer's shuttle bus showed the highest happiness compared with the other modes. This may be linked to the ease of commuting and pecuniary benefit. Zhu and Fan (2018b) analyzed the wellbeing of commuters in the U.S. and found that public transport commuters showed the least happiness and that long trips had a negative impact on the happiness level. Thus, this paper posits that shorter travelling time, which is one of the expected outcomes of tram fare removal, might have a positive impact on the tram users' utility and happiness level. It is also a possible outcome that a higher level of satisfaction is positively capitalized in the house prices as well.

8) https://www.abc.net.au/news/2014-03-26/state-government-to-cut-the-cost-of-train2c-tram-travel/5345652

9) The new fare was $3.76 for zone 1 or zone 1 + zone 2, and $2.60 for a zone 2 trip.

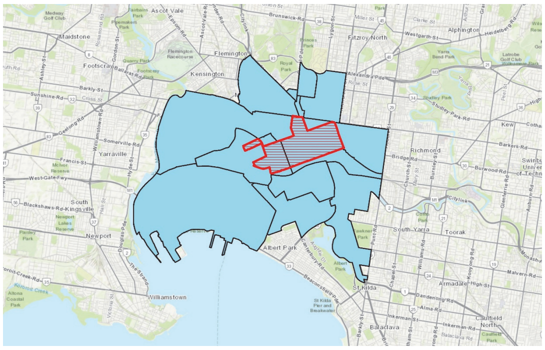
10) When the irregular shape is removed, the vertical and horizontal distances are 0.98km and 2.5km respectively.

IV. Data and methodology

1. Data

This paper uses transaction data from CoreLogic RP Data, a private data provider in Australia. The free tram zone is a small area that includes parts of two post codes 3000, and 3008. Thus, all the transaction records are collected from two post code areas at the first stage. The data period ranges from January 2012 to December 2017. Secondly, eight surrounding post codes are added to the sample. A total of 16,635 transactions are collected and geocoded with ArcGIS software to see if the property is located in the free tram zone or not.

<Figure 3> Control and treatment area by postal code



Note: This figure shows the treatment and control area used for this study. The area colored blue indicates the total sample area including 13 post codes. The area colored red is the treatment area (i.e. the free tram zone).

<Figure 3> shows the area of the free tram zone and the geographical area of sample data. The blue area contains 13 post codes which include the two post code areas containing the free tram zone. Three post codes are excluded from this study because they contain only non-residential properties[11].

<Table 1> Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Panel I: Total sample					
W_price	16,635	582,810	305,630	181,200	1,400,000
bed	16,635	1.74	0.75	0	4
bath	16,635	1.24	0.65	0	3
car	16,635	0.93	0.68	0	3
Panel II: FTZ					
W_price	6,011	496,891	266,229	181,200	1,400,000
bed	6,011	1.63	0.68	0	4
bath	6,011	1.03	0.66	0	3
car	6,011	0.72	0.70	0	3
Panel III: Outside 100m					
W_price	657	592,856	282,074	181,200	1,400,000
bed	657	1.53	0.79	0	4
bath	657	1.49	0.60	0	3
car	657	0.86	0.61	0	3
Panel IV: Control					
W_price	9,981	634,148	317,749	181,200	1,400,000
bed	9,981	1.81	0.78	0	4
bath	9,981	1.34	0.61	0	3
car	9,981	1.07	0.64	0	3

Note: This table shows the descriptive statistics of key variables. Panel I reports the summary statistics from total samples while Panel II reports the summary statistics from samples located within the free tram zone. Panel III reports the summary statistics from the samples located within 100 meters from the boundary of the free tram zone. Panel IV summarizes key variables from samples located outside it. All the key variables are winsorized as explained in the data section.

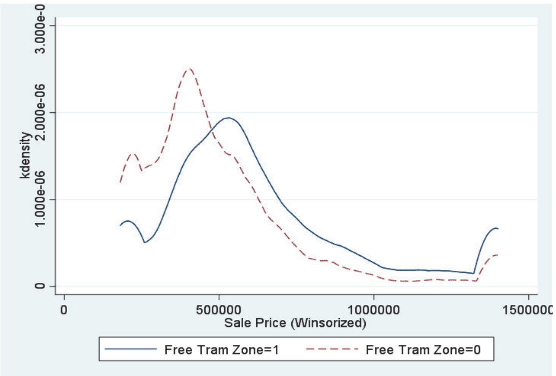
Transaction data contain transaction date, price, number of bedrooms, number of bathrooms, and number of parking areas. The transaction price is winsorized at the 5% and 95% level[12]. Number of bedrooms, bathrooms, and parking spaces is winsorized at 1% and 99% level.

11) The post codes excluded in this study are 3005, 3010, and 3050. 3005 contains only commercial properties; 3010 is solely used for Melbourne University; 3050 is used for the Royal Melbourne Hospital. Thus, this study uses post codes consisting of 3000, 3002, 3003, 3004, 3006, 3008, 3051, 3053, 3205, and 3207.

12) 5% winsorization is applied to the transaction price as the 1% winsorization makes the lowest winsorized price at $55,000, which is not realistic. At 5% winsorization, the lowest price is %181,200 and this price range makes more sense in reality.

<Table 1> shows the summary statistics of major variables in the treatment and the control area. The mean price in the free tram zone is $496,891, which is lower than the mean price in the control area (outside the free tram zone). The maximum number of bedrooms and bathrooms is 4 and 3 in both groups[13]. In Panel III, the summary of subsamples located within 100 meters from the boundary of the free tram zone is reported[14].

<Figure 4> Kernel density of sale price in the treatment area (free tram zone) and the control area



Note: This figure reports the price distribution for real estate transactions in the free tram zone and the surrounding area between January 2012 and December 2017. The solid blue line is the price distribution in the free tram zone, while the dotted line indicates the price distribution of the surrounding control area.

Winsorized sale prices are plotted in the kernel density graph in <Figure 4>. The vertical axis is density level and the horizontal axis shows winsorized sale price. The solid blue line indicates the price density from the transacted properties located within the free tram zone, whereas the dotted red line stands for the density level of prices from the properties located in the control area surrounding the free tram zone. In general, the peak of the density in the control area is clustered at the lower price level compared to the price level of the treatment area (free tram zone).

In the time falsification analysis, the data period is redesigned to contain transactions from January 2009 to December 2014. In this analysis, 10,952 transactions are identified for analysis and each variable is winsorized in the same way as the baseline analysis. Of 12,378 transactions, 4,446 samples are located in the free tram zone, and 7,932 properties are located in the control area. In this analysis, a falsified fare removal date is arbitrarily set and used to sort treatment time and control time. To alleviate the concerns about a single arbitrary date, average results from 1000-time falsification simulation are presented.

2. Methodology

This paper uses 16,635 transactions from the 13 post code areas including the free tram zone and its surrounding area. Followed by Diao et al. (2017) and Pope and Pope (2015), a difference-in-difference (DID) method is adopted in this study. Diao et al. (2017) used the DID method to estimate the impact of new subway line in Singapore and Pope and Pope (2015) used the DID method to find the house price change when Walmart was newly introduced in each treated area. Firstly, transacted properties within the free tram zone are identified by the transaction date in this study. Separate dummy variables are classified for property transactions located within the free tram zone (*Freetram*)

13) Samples include condominiums used for student housing. These condominiums are similar to residential studio in the U.S. Bathrooms are shared by the residents in the complex. Thus, the minimum number of bedrooms and bathrooms is zero.

14) In this study, treatment and control group vary as the distance buffer zone is controlled for in separate models. In the baseline analysis, the treatment group contains transactions from panel II, while the treatment group is enlarged with additional treatment groups located within each distance buffer in other analysis with distance buffer specification.

and with a transaction date after January 1, 2015 (*After*), which is the effective date of the tram fare removal. Log-normalized transaction price is regressed on the hedonic attributes including number of bedrooms, number of bathrooms, and number of parking spaces in addition to controlling for the treatment group (*Freetram*), the treatment time (*After*), and the interaction term of the two. Due to the downward bias of standard errors when clustering effects are omitted, the standard errors are clustered at the suburb level throughout the analysis in this paper, as suggested by Bertrand et al. (2004) and Cameron and Miller (2015). Both year and month fixed effects are included in each regression, and additional analysis with the fixed effect of year X month is conducted as well. Administrative district fixed effects, such as postcode fixed effect or suburb fixed effect, are included in the model to distinguish the idiosyncratic traits of each area. The model specification of the baseline analysis is as follows:

$$\ln(\mathrm{Price}_{i,t}) = \alpha + \beta_1(Freetram\,XAfter) + \beta_2(Freetram) + \beta_3(After) + X'_{i,t}\theta + \gamma_t + \delta_{district} + \epsilon_{i,t} \quad Eq(1)$$

where β_1 is a coefficient on the interaction term of *After* and *Freetram*; X' stands for hedonic factors; γ_t is time fixed effect; $\delta_{district}$ is administrative district fixed effect such as postcode or suburb fixed effect; and $\epsilon_{i,t}$ is an error term. If the transacted property is located within the free tram zone, *Freetram* equals 1 and 0 otherwise. When the transaction date is after the tram fare removal date (January 1, 2015), the dummy variable, *After*, is 1 and 0 otherwise.

In the boundary impact analysis, additional dummy variables for certain Euclidean distance-based buffers are added. This analysis is included in order to see if the impact of the tram fare removal is capitalized in the unaffected but near area from the free tram zone. Givord et al.(2013) used a similar concept to find if there were any negative spillover impact after introducing a place-based tax exemption policy and found that the area surrounding the tax-exempt area had experienced negative externality. To compare the responsiveness in distance from the border of the zone, separate dummy variable is controlled for by grouping the transactions located within the Euclidean distance of 0-100 meter and 100-200 meter. Following Pope and Pope (2015), a few dummy variables with distance interval from the FTZ boundary are add to the previous base model as shown in Eq (2)[15]. The model specification for the boundary impact analysis is described below.

$$\ln(\mathrm{Price}_{i,t}) = \alpha + \beta_1(Freetram\,XAfter) + \beta_2(Outside\,100m\,XAfter) + \beta_3(Outside\,200m\,XAfter) + \beta_4(Freetram) + \beta_5(Outside\,100m) + \beta_6(Outside\,200m) + \beta_7(After) + X'_{i,t}\theta + \gamma_t + \delta_{district} + \epsilon_{i,t} \quad Eq(2)$$

All the variables are identified in the same way as in Eq (1) except for dummy variables of *Outside 100m* and *Outside 200m*. *Outside 100m (200m)* takes 1 if the transacted property is located within 0-100m (100-200m) buffer zone from the boundary of the free tram zone, otherwise 0. The average distance between tram stations in Melbourne is known to be 200 meters. Thus, using 100m and 200m dummy variables is considered to be a plausible model specification.

15) Dummy variables with distance interval can be added as many time as possible. However, in this study, it is found that the significant impact does not affect wider range of the area. Thus, only two variables that covers both 0-100 meter area and 100-200 meter area are included. Adding more dummy variables, such as a dummy for 200-300 meter does not change the major finding of this paper.

One of the requirements when using the difference-in-difference method is to show a common trend in the pre-treatment period. This paper shows the common trend before the treatment date by regressing the price on divided terms before the fare removal date instead of using graphic figures with mean or median price. More specifically, total samples from January 2010 to December 2014 are pooled together and divided into two terms: 1: 2010-12:2013; 1:2014-12:2014. The first term is used as a reference period, while the second term is classified as pre-treatment (Before) period. The model specification for common trend analysis is as follows.

$$\ln(\mathrm{Price}_{i,t}) = \alpha + \beta_1(Freetram\,XBefore) + \beta_2(Outside\,100m\,XBefore) + \beta_3(Freetram) + \beta_4(Outside\,100m) + \beta_5(After) + X'_{i,t}\theta + \gamma_t + \delta_{district} + \epsilon_{i,t} \quad Eq(3)$$

If the results from Eq (3) find any significant response from the interaction terms (i.e. *Freetram X Before* or *Outside 100m X Before*), the common trend assumption is not satisfied. In other words, the coefficient of β_1 and β_2 should be insignificant, which confirms that there are no significant differences from the reference period before the tram fare removal.

V. Empirical results

In this section, the specification of baseline model Eq (1) with total sample is tested first. Then, boundary impact analysis is conducted based on the Eq (2). Lastly, the common trend analysis is reported. From the baseline model, no significant movement in transaction price is captured. However, in the boundary impact analysis, condominiums located near the free tram zone boundary show significant price increases after the removal of tram fares. The results find that properties located closer to the border of the free tram zone are affected positively, which indicates that the fare removal helps expand the CBD boundary. The common trend analysis confirms that there are no significant differences in price trend before the fare removal compared with the reference period.

1. Baseline model

<Table 2> reports the results from the baseline model as specified in Eq (1).

<Table 2> Baseline model on impact of tram fare removal

	(1)	(2)	(3)	(4)
VARIABLES	ln(price)			
Freetram X After	0.008	0.012	0.005	0.008
	(0.38)	(0.43)	(0.18)	(0.26)
Freetram	-0.085	-0.158***	-0.083	-0.156***
	(-1.54)	(-12.83)	(-1.57)	(-14.61)
After	0.100**	0.096**	0.139***	0.147***
	(3.07)	(2.72)	(5.22)	(5.66)
# of Bedroom	0.219***	0.219***	0.221***	0.220***
	(6.41)	(6.45)	(6.93)	(6.97)
# of Bathroom	0.111***	0.108***	0.111***	0.109***
	(5.24)	(5.21)	(5.16)	(5.12)
# of Car Park	0.115***	0.124***	0.116***	0.125***
	(5.17)	(5.22)	(5.60)	(5.63)
Constant	12.303***	12.064***	12.311***	12.063***
	(105.97)	(164.25)	(113.72)	(185.44)
Observations	16,635	16,635	16,635	16,635
R-squared	0.460	0.455	0.467	0.462
Year fixed effect	YES	YES	NO	NO
Month fixed effect	YES	YES	NO	NO
Year X Month fixed effect	NO	NO	YES	YES
Postcode fixed effect	YES	NO	YES	NO
Suburb fixed effect	NO	YES	NO	YES

Note: This table exhibits the results of regressing the log-normalized price on the interaction term of a dummy variable for an ex-post period of fare removal and free tram zone, and other hedonic variables. Hedonic variables include the number of bedrooms, bathrooms, and parking spaces. The post code fixed effect is included in column (1) and (3), while column (2) and (4) use suburb fixed effect. Column (1)-(2) includes year and month fixed effect separately, while column (3)-(4) contains year X month fixed effect. Standard errors are clustered at suburb level. Robust T-statistics are given in parentheses. ***significant at 1 percent, ** 5 percent, * 10 percent.

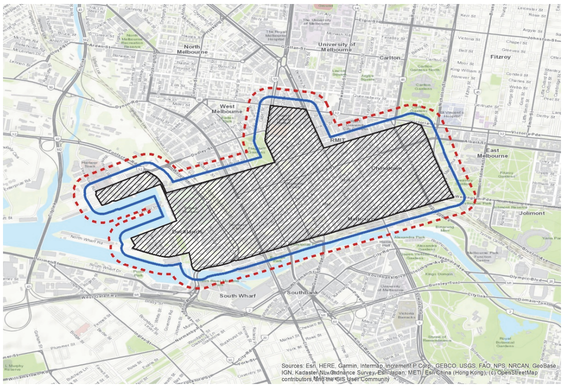
The coefficient of interest is the interaction term '*Freetram X After*'. Contrary to the anticipated positive capitalization conjectured by the previous literature, the results find no significant change in price after the tram fare removal. Column (1) and (2) show results with separate year and month fixed effects in addition to the post code and suburb fixed effect, while column (3) and (4) report results from the interaction fixed effect of year and month. From column (1) to (4), the response is very weak and statistically insignificant. All the coefficients of hedonic variables show positive relationships as expected. Thus, the results indicate that the fare removal does not affect the price level within the free tram zone.

2. Boundary impact analysis

Even though the average price level in the free tram zone does not respond after the fare removal, it is also possible that properties located outside the free tram zone might respond. To study the unexpected response in the outer area, two zones with 100-meter buffers are analyzed separately. For clearer comparison, two rings with 100-meter buffer (i.e. 0-100m and 100-200m) are studied in this section to capture the different responses in distance as shown in <Figure 5>.

<Table 3> shows the price change in the two distance buffer zones after fare removal. Column (1) and (2) uses Year and Month fixed effect separately, while column (3) and (4) includes Year X Month fixed effect. Like Table 2, column (2) and (4) include the suburb fixed effect. This table reports that prices increase by 8.7% to 10.7% in the 0-100m buffer ring[16]. Thus, this table indicates that the benefit from the fare removal is positively capitalized in the near area from the boundary of the free zone.

<Figure 5> 100-meter and 200-meter buffer area



Note: This figure shows the 100-meter and 200-meter buffer area used in boundary impact analysis in Table 3. Each buffer line is drawn from the nearest line from the boundary of the free tram zone.

The distance buffer is drawn by the direct Euclidean distance from the boundary, which means that the actual walking distance could be longer than the direct distance. Thus, people who used to pay for tram rides can walk to the free tram zone and save commuting cost accordingly. Also, due to the larger coverage of the post code area than the suburb coverage, the results with suburb fixed effect gain more credit in the analysis. So, the time-invariant negative price gap by almost 12% is narrowed by 10.1% to 10.7% after fare removal.

16) This result can be explained in a 2X2 matrix with before-after, and control-treated classification. For example, the result from column (1) can be classified by the Eq(2) specification as follows:

	Before	After	Difference
Control	α (12.26)	$\alpha+\beta_7$ (12.359)	0.099
Treated(Outside 100m)	$\alpha+\beta_5$(12.256)	$\alpha+\beta_2+\beta_5+\beta_7$(12.448)	0.192
Difference	-0.004	0.089	0.093

<Table 3> Boundary impact analysis

	(1)	(2)	(3)	(4)
VARIABLES	ln(price)			
Freetram X After	0.011	0.012	0.007	0.008
	(0.50)	(0.47)	(0.26)	(0.26)
Outside 100m X After	0.093**	0.107**	0.087**	0.101***
	(2.45)	(3.04)	(2.84)	(3.63)
Outside 200m X After	-0.049	-0.054	-0.051*	-0.056*
	(-1.72)	(-1.56)	(-2.13)	(-1.88)
Outside 100m	-0.004	-0.122***	-0.009	-0.123***
	(-0.05)	(-4.24)	(-0.10)	(-4.49)
Outside 200m	0.119	0.041	0.117	0.040
	(1.17)	(0.75)	(1.15)	(0.75)
Freetram	-0.045	-0.166***	-0.047	-0.165***
	(-0.45)	(-8.21)	(-0.46)	(-8.61)
After	0.099***	0.097**	0.141***	0.151***
	(3.28)	(2.97)	(5.06)	(5.37)
# of Bedroom	0.221***	0.218***	0.222***	0.220***
	(6.51)	(6.58)	(6.93)	(7.05)
# of Bathroom	0.109***	0.109***	0.109***	0.110***
	(5.16)	(4.98)	(5.12)	(4.96)
# of Car Park	0.117***	0.123***	0.118***	0.124***
	(5.33)	(5.09)	(5.70)	(5.41)
Constant	12.260***	12.064***	12.268***	12.060***
	(77.37)	(161.09)	(77.97)	(177.20)
Observations	16,635	16,635	16,635	16,635
R-squared	0.461	0.456	0.468	0.463
Year fixed effect	YES	YES	NO	NO
Month fixed effect	YES	YES	NO	NO
Year X Month fixed effect	NO	NO	YES	YES
Postcode fixed effect	YES	NO	YES	NO
Suburb fixed effect	NO	YES	NO	YES

Note: This table reports the results of regressing the log-normalized price from the transacted condominiums located in the free tram zone, 0-100m buffer, and 100-200m buffer from the boundary. Hedonic variables include the number of bedrooms, bathrooms, and parking spaces. The postcode fixed effect is included in column (1) and (3), and column (2) and (4) include suburb fixed effect. Column (1)-(2) includes year and month fixed effect separately, while column (3)-(4) contains year X month fixed effect. Standard errors are clustered at post code level. Robust T-statistics are given in parentheses. ***significant at 1 percent, ** 5 percent, * 10 percent.

However, it is questionable why the price of condominiums within the free tram zone does not change. The area of the free tram zone is approximately 2.843 square kilometers and the longest distance of the free tram zone is less than 3 kilometers. As most workplaces are concentrated in the center of the free tram zone, the residents living in the city center could already walk to the workplaces rather than using tram services.

However, those living close to the boundary of the free tram zone are more likely to take a tram for commuting, as they do not live within walking distance from the city center. Moreover, 2016 Census report of Australia reports that 36.1% of postcode 3000 area and 24% of 3008 area walk to workplace in contrast to the Victoria's average at 3.2% of pedestrian commuters, and all the transactions in the FTZ area in this study belong to either 3000 or 3008 postcode area. So, even before the introduction of the free tram zone, it is likely that many residents within the FTZ were already commuting to workplace on foot. One more thing to note is the interaction of contradicting forces after the introduction of FTZ. As introduced in the literature review section, extant papers argue that there are both positive and negative amenities that can be resulted from the free fare transport. Especially, the researchers were concerned about higher foot traffic, quality of transport service, sustainability, and rowdiness in the area. Thus, the other way to explain the insignificant response is that both positive and negative forces are cancelled out leaving insignificant response in condo price. In contrast to the FTZ, the surrounding area is unlikely to suffer from such negative externality. Thus, the negative impact of fare removal can be considered to be one of the channels that make the price change in the FTZ muted compared with the surrounding area with significant increase in price. More recently, there was an inquiry into expanding the free tram zone in order to provide more benefit to the society in 2020. However, in the inquiry submitted to the parliament of Victoria[17], it was found that the anticipated negative impact really did happen within the free tram zone. Yarra Tram, the operator of tram service in the subject area, reported that the major concern is related with the passenger safety issues as the FTZ covers most crowded areas with tram services. Even though it was anticipated that skipping the ticketing system (i.e. tapping on the tram care reader) would shorten the travelling time, it causes more passenger falls. It was reported that the FTZ accounts for 27% of tram network, while total passenger falls in the FTZ constitute 47% of total passenger incidents. Also, a complaint about the displacement of usual passengers due to the overcrowding was presented by the Department of Transport. Considering the academic conjecture and actual witness from the paper submitted to the Parliament, it can be inferred that the positive impact of the FTZ is muted by the negative impact of the FTZ designation.

3. Common trend analysis

The use of difference-in-difference relies on the assumption of a common trend before the change in fare structure. If treatment group and control group do not show common trend before the treatment, any significant differences after the treatment would not be reliable. To alleviate this concern, a common trend analysis is undertaken in this section. In order to do this, two separate terms are designed to include a reference period, and a pre-treatment period. The reference period includes all transactions from January 2010 to December 2013; the pre-treatment period contains transactions from January 2014 to December 2014. The model specification for common trend analysis is described in Eq (3).

<Table 4> Common trend analysis

	(1)	(2)	(3)	(4)
VARIABLES	ln(price)			
Outside 100m X Before	0.046	0.044	0.044	0.042
	(1.15)	(1.05)	(1.02)	(0.92)
Freetram X Before	0.022	0.026	0.018	0.022
	(0.36)	(0.42)	(0.31)	(0.36)
Outside 100m	-0.144*	-0.205***	-0.143*	-0.204***
	(-2.09)	(-8.28)	(-2.03)	(-7.87)
Freetram	-0.187**	-0.257***	-0.186**	-0.256***
	(-2.45)	(-9.43)	(-2.44)	(-9.36)
Before	0.028	0.030	0.129*	0.133*
	(1.21)	(1.27)	(1.98)	(2.01)
Observations	10,952	10,952	10,952	10,952
R-squared	0.484	0.483	0.486	0.484
Year fixed effect	YES	YES	NO	NO
Month fixed effect	YES	YES	NO	NO
Year X Month fixed effect	NO	NO	YES	YES
Postcode fixed effect	YES	NO	YES	NO
Suburb fixed effect	NO	YES	NO	YES

Note: This table reports the results of regressing the log-normalized price from 2010 to 2014 with the first three years as reference period and the last year as the pre-treatment period. Other hedonic variables are controlled for but not reported in this table due to space limitation. Standard errors are clustered at suburb level. Robust T-statistics are given in parentheses. ***significant at 1 percent, ** 5 percent, * 10 percent.

<Table 4> shows the results of common trend analysis. The coefficients of interest are '*Freetram X Before*' and '*Outside 100m X Before*'. If the two groups from *Freetram* and *Outside 100m* had significant deviation from the reference group during the one-year period before the tram fare removal, the coefficients of '*Freetram X Before*' and '*Outside 100m X Before*' should be significantly different from zero. However, as <Table 4> shows, all the coefficients of variables interacted with *Before* are statistically insignificant. This result confirms the validity of the results in <Table 3> by satisfying the common trend assumption.

4. Robustness test and confounding factor

In order to check the validity of the model specification, different model specification is

17) https://www.parliament.vic.gov.au/file_uploads/LCEIC_59-03_Expanding_Melbourne_s_Free_Tram_Zone_J2t4J9sH.pdf

used in this section. By the specification of the difference-in-difference method, the effects from the unobserved variables are excluded in the analysis. However, to make the results more reliable, distance to the nearest tram stops in the free tram zone is added to the model to see if omitted variable has affected the results. <Table 5> reports the results of the regression with distance to tram stop. The coefficients of *Outside 100m X After* is economically weaker but they are still economically and statistically significant. Additionally, the coefficients of Distance to Tram Station are close to zero, which indicates that additional control does not change the results.

Moreover, the possibility that other events might have happened in similar time frame and affected the price change cannot be excluded. One event that happened in 2015 was the renovation project of the Queen Victoria Market (QVM), which is the largest traditional marketplace in Melbourne. The QVM is one of the tourists' hotspots in Melbourne and enjoyed by the local residents. So, living close to the QVM indicates that the residents near the QVM enjoy positive amenity. The utility level of the residents in the QVM area might be enhanced after the renovation project is complete. <Table 6> showcases the results from the confounding factor analysis with the QVM renovation. Distance to the QVM from each transacted property is controlled for in this analysis. As <Table 6> reports, the coefficients of *Distance to QVM* are zero.

<Table 5> Robustness test - distance to tram stop

VARIABLES	(1)	(2)	(3)	(4)
	ln(price)			
Freetram X After	0.009	0.012	0.006	0.009
	(0.44)	(0.50)	(0.21)	(0.28)
Outside 100m X After	0.094**	0.100**	0.088**	0.095***
	(2.37)	(2.85)	(2.74)	(3.37)
Outside 200m X After	-0.049	-0.051	-0.052*	-0.053*
	(-1.73)	(-1.62)	(-2.14)	(-1.97)
Distance to Tram Station	-0.000	0.000	-0.000	0.000
	(-1.35)	(1.45)	(-1.37)	(1.31)
Constant	12.281***	12.035***	12.297***	12.031***
	(74.71)	(133.72)	(74.96)	(137.82)
Observations	16,635	16,635	16,635	16,635
R-squared	0.462	0.457	0.469	0.464
Year fixed effect	YES	YES	NO	NO
Month fixed effect	YES	YES	NO	NO
Year X Month fixed effect	NO	NO	YES	YES
Postcode fixed effect	YES	NO	YES	NO
Suburb fixed effect	NO	YES	NO	YES

Note: This table reports the results of different model specification by adding the distance to the nearest free tram stops. Hedonic variables are controlled for but not reported in this table due to space limitation. Robust T-statistics are given in parentheses. ***significant at 1 percent, ** 5 percent, * 10 percent.

<Table 6> Confounding factor analysis - distance to Queen Victoria Market

VARIABLES	(1)	(2)	(3)	(4)
	ln(price)			
Freetram X After	0.012	0.015	0.008	0.010
	(0.60)	(0.66)	(0.31)	(0.38)
Outside 100m X After	0.089**	0.093***	0.084***	0.088***
	(2.91)	(3.57)	(3.38)	(4.18)
Outside 200m X After	-0.048	-0.049	-0.050*	-0.051
	(-1.53)	(-1.43)	(-1.88)	(-1.72)
After	0.099***	0.096**	0.132***	0.144***
	(3.57)	(3.11)	(4.94)	(5.17)
Distance to Tram Station	-0.000*	-0.000	-0.000*	-0.000
	(-2.11)	(-1.25)	(-2.18)	(-1.30)
Distance to QVM	0.000	0.000	0.000	0.000*
	(1.24)	(1.77)	(1.29)	(1.86)
Constant				
	16,635	16,635	16,635	16,635
	0.466	0.462	0.472	0.469
Observations	16,635	16,635	16,635	16,635
R-squared	0.461	0.462	0.472	0.469
Year fixed effect	YES	YES	NO	NO
Month fixed effect	YES	YES	NO	NO
Year X Month fixed effect	NO	NO	YES	YES
Postcode fixed effect	YES	NO	YES	NO
Suburb fixed effect	NO	YES	NO	YES

Note: This table reports the results of different model specification that includes the control for the renovation project of the Queen Victoria Market by adding the distance to the QVM. Hedonic variables are controlled for but not reported in this table due to space limitation. Robust T-statistics are given in parentheses. ***significant at 1 percent, ** 5 percent, * 10 percent.

5. Falsification analysis

This section documents the results from the falsification analysis with an arbitrarily set tram fare removal date.

To conduct this analysis, January 1, 2013 is set as a falsified tram fare removal date. Then, the price levels within the free tram zone and the surrounding post code areas are compared followed by Eq (2). <Table 7> reports the results from replicated analysis of <Table 3> with the falsified fare removal date. As with the interpretation of <Table 3>, the coefficient of interest is the point estimate of the interaction term.

<Table 7> Time falsification analysis

	(1)	(2)	(3)	(4)
VARIABLES	ln(price)			
Freetram X False Time	0.006	0.010	0.002	0.006
	(0.12)	(0.21)	(0.04)	(0.13)
Outside 100m X False Time	0.011	0.012	0.009	0.010
	(0.41)	(0.42)	(0.28)	(0.29)
Outside 200m X False Time	0.016	0.016	0.014	0.015
	(0.34)	(0.34)	(0.32)	(0.32)
Outside 100m	-0.091	-0.175***	-0.090	-0.173***
	(-1.01)	(-4.75)	(-0.98)	(-4.64)
Outside 200m	0.023	-0.034	0.025	-0.032
	(0.29)	(-0.35)	(0.32)	(-0.34)
Freetram	-0.163	-0.255***	-0.162*	-0.253***
	(-1.83)	(-10.64)	(-1.85)	(-10.74)
False Time	0.133***	0.133***	0.170**	0.170**
	(5.24)	(5.20)	(2.71)	(2.68)
# of Bedroom	0.219***	0.219***	0.219***	0.219***
	(9.64)	(9.69)	(9.81)	(9.86)
# of Bathroom	0.160***	0.159***	0.160***	0.159***
	(10.52)	(10.35)	(10.17)	(9.99)
# of Car Park	0.055***	0.057***	0.056***	0.058***
	(3.41)	(3.34)	(3.69)	(3.60)
Constant	12.281***	11.966***	12.299***	11.985***
	(93.59)	(175.97)	(80.31)	(132.77)
Observations	12,378	12,378	12,378	12,378
R-squared	0.489	0.487	0.492	0.490
Year fixed effect	YES	YES	NO	NO
Month fixed effect	YES	YES	NO	NO
Year X Month fixed effect	NO	NO	YES	YES
Postcode fixed effect	YES	NO	YES	NO
Suburb fixed effect	NO	YES	NO	YES

Note: This table reports the results from time falsification analysis with an arbitrary date of tram fare removal. Falsified tram fare removal date is set as January 1, 2013. Same variables are used as in Table 3. Standard errors are clustered at post code level. Robust T-statistics are given in parentheses. ***significant at 1 percent, ** 5 percent, * 10 percent.

The coefficients of '*Outside 100m X After*' are statistically and economically insignificant. However, designating a few specific scenarios of falsification analysis might result in an insignificant response by chance. Thus, in the following analysis, falsification analysis in time and location is tested 1000 times with randomized treatment time.

A random combination of year, month, and day is chosen between January 1, 2010 to December 31, 2013. A false tram fare removal date is arbitrarily generated based on the random date, and the same regression analysis is replicated 1000 times. The average coefficient, t-statistics, and p-values are reported afterwards. <Table 8> reports the results of simulation tests. The average coefficients are close to zero and the t-statistics and p-values indicate that the results are statistically insignificant. These results confirm that the falsification results in <Table 7> are not just coincidences.

<Table 8> Simulation of location and time falsification analysis

	(1)	(2)	(3)	(4)
	Time Falisification (1000 times)			
VARIABLES	ln (price)			
Outside 100m X False Time	-0.004	-0.004	-0.008	-0.002
T-statistics	-0.056	-0.071	-0.193	-0.057
P-Value	0.596	0.563	0.597	0.600
Hedonic Variables	YES			
Year fixed effect	YES	YES	NO	NO
Month fixed effect	YES	YES	NO	NO
Year X Month fixed effect	NO	NO	YES	YES
Postcode fixed effect	YES	NO	YES	NO
Suburb fixed effect	NO	YES	NO	YES

Note: This table reports the average coefficients, t-statistics, and p-values from time and location falsification analysis. The falsified tram fare removal date is randomly chosen for the time falsification analysis. Both time falsification test is replicated 1000 times with different fixed effect specifications through column (1) to (4). Standard errors are clustered at suburb level. Robust T-statistics are given in parentheses. ***significant at 1 percent, ** 5 percent, * 10 percent.

Ⅵ. Conclusion

The relationship between urban living and transportation has been long studied in the extant literature. In particular, many researchers have tested the impacts of increased transport costs or the change of gasoline price. However, studies of the impact of fare removal on real estate prices are scant. This paper investigates the impact of tram fare removal in Melbourne, Australia on the real estate price, by using the condominium transaction data, the difference-in-difference method, and the distance impact analysis. A total of 16,635 residential condominiums are analyzed during the study period which covers the three years before and after the fare removal date. Additional transaction samples from 2009 to 2014 are used in a falsification analysis with arbitrary fare removal dates.

After the tram fare removal within the designated city center area, it is found that the price of residential condominiums transacted in the free tram zone does not, on average, change significantly. However, when condominiums located near to the boundary of the free tram zone are separately analyzed, condominiums within 100-meter buffer respond positively by 8.7% to 10.7%. This significant increase in transaction price seems to be related to the benefit of saving travelling cost by living close to the boundary of the free tram zone. Considering the geographic size of the free tram zone, the residents in the city center are less likely to use trams due to the proximity of their work. In contrast, it is more likely that residents living close to the boundary of the free tram zone are the ones to receive the benefit of tram fare removal. It is also found that the significant response is muted in 100-200m buffer area, which indicates that the benefit is capitalized only when the distance to the free tram zone is conspicuously close. Additional falsification analysis with the randomized time of fare removal and false free tram zone confirms that the significant response is seen only after the actual tram fare removal and within the free tram zone. Adding control variable, such as the distance to the closest tram stop within the free tram zone, or using alternative confounding event do not alter the tenor of the major finding of this paper.

This paper contributes to the existing literature in a few respects. First, it documents the impact of tram fare removal on the house price, which is rarely studied, while extant papers studied the changes in transport demand or transport users' behavior. While most transport policies focus on increasing the existing fare or toll or implementing a new road pricing scheme, the contribution of this paper lies on the point that the relationship between free fare and the housing price, especially the impact of spillover, is studied empirically. By studying the natural experiment of fare removal, this paper reports that the benefit of fare removal is also enjoyed by the residents living outside of the free tram zone. Secondly, this paper can be linked to the literature on the expansion of cities by showing the narrower gap between the CBD area and 100-meter buffer area after the fare removal. While residents in pertinent area may be concerned about higher foot traffic, which can negatively affect the real estate price, the results of this paper indicate that the general change in house prices is muted in the central area but positive towards the outer boundaries. In terms of policy implication, it is recommended that other governments or municipalities considering removal of public transportation modes, the impact of fare removal on the urban context should be considered in addition to the context of transportation engineering or cost-benefit analysis. In case of Korea, similar policies have been introduced and implemented in some municipalities. Also, partial fare-free public transport scheme for marginalized classes, such as elderly people or the handicapped, has been known to be successful for long time. However, as seen in the cities of the U.S., the loss incurred by the free fare system causes deficit in budget and makes the free fare policy abolished in the end. In Korea, it is known that the fare free policy for senior passengers once accounted for 71% of total loss in the subway operation. As this paper finds, if the tax authorities can collect more tax due to the value increase in real estate after the implementation of transport policy, allocating the tax increment to compensate the loss in transportation system would be a plausible idea.

Much broader study is required to understand and estimate the potential impact of transport policy such as fare removal program as such program can accelerate the speed of urbanization or gentrification in terms of transaction price as seen in this paper. Also, existing papers argue that there might be quite a few cases with negative externalities when the public transport fare is removed.

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<국문요약>

교통요금 면제와 주택 가격-멜버른의 case 연구

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본 연구는 교통정책과 부동산의 관계를 연구한 논문으로써, 호주 멜버른 도심의 트램 요금 면제가 부동산 시장에 미친 영향을 분석 대상으로 하였다. 2015년 1월 무료화된 멜버른 도심의 트램 시스템은 요금제도의 문제점을 보완하기 위하여 소개되었으며, 도입 당시 긍정 및 부정적 영향에 대한 우려가 있었다. 트램 면제 지역과 주변지역의 콘도미니엄 가격을 DID기법을 사용하여 분석해본 결과, 요금 면제 지역 안에 위치한 콘도는 가격 변화가 없었으나, 트램 요금 면제 구역에서 직선거리로 100미터 이내에서 거래된 콘도들의 가격은 8.7%에서 10.7%의 가격 상승 추세를 보였다. 요금 면제 구역에 위치한 가장 가까운 트램 역에 대한 통제나 시내 명소에 대한 거리를 추가적으로 통제하였을 경우에도 결과는 변화가 없었다. 무작위로 선정된 트램 요금 면제일자를 사용하여 1000회 시뮬레이션 해본 결과, 다른 임의의 요금 면제 일자에서는 유의한 반응이 나오지 않았다. 이는 트램 요금 면제가 도보 거리에 있는 거주지에 긍정적 가격 영향을 미쳤음을 확인해준다. 또한, 요금 폐지는 트램 과밀현상, 낙상사고 등의 부정적 요소를 야기시키는 것으로 알려졌고, 이는 트램 요금 면제 지역 내에서의 유의하지 않은 반응을 뒷받침해준다.

주 제 어 : 부동산 가격, 대중 교통, 대중교통 요금 면제, 교통 요금, 트램