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Impact of urban railway announcements on housing market: Preponderance of pre-construction and post-construction phase effect of urban railway projects

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ABSTRACT

The increasing concerns arising from measuring the effect of metro railway line projects on the sale prices of surrounding housing within urban spaces have been addressed in a vast number of related studies. However, potential changes in these effects with regard to short-run and long-run equilibriums have not been studied satisfactorily in developing countries. Therefore, this paper measures the effect of metro railway line investments on housing sale prices with respect to two different stages of related projects: pre-construction stage and post-construction stage, in two similar study areas in İstanbul, Turkey. The prices of houses are modeled using hedonic price models. The results indicate that housing sale prices before construction (announcement) of the metro railway line projects increase almost twofold after construction. In addition, the paper employs a before and after analysis to measure the effect of the different stages of metro railway line investments on housing sale prices. The results reveal that the average price increase of a housing unit in the pre-construction phase of the metro railway line project is 86,756.37 TL greater than the average price increase in the post-construction phase. Thus, the validity of the speculated effect of such urban railway investments on housing sale prices is justified.

1. Introduction

Transportation systems play an important role in the social and economic development of urban life. In the modern world, they are regarded as one of the basic public infrastructures that shape urban macroform and provide city scale connectivity. According to Burdett (2018), transportation is one of the requirements in urban life that forms the city, along with sanitation, water supplies, waste disposal, and telecommunications.

The importance of transportation systems means they inevitably trigger an increase in land values. Urban railway corridors have the greatest impact on land value as they provide immediate accessibility to and between uses with a high quality service (Harjunen, 2018; Muth, 1969; Mills, 1972; Mills, 2000; Burdett, 2018).

Land value changes in developing countries are different to those in developed countries where accessibility patterns are already established. In the short-run or partial equilibrium, capitalised cost means that the value of urban lands located around the investment tends to increase. This increase has been measured and demonstrated multiple times in developing countries, where there are insufficient transit or urban railway investments (Forouhar and Hasankhani, 2018; Surbhi, 2019). Furthermore, the related difference between short-run and long-run equilibrium effects is justified by the empirical findings of our study. This has been achieved by comparing the effect of metro railway line investments on hosuing sale prices in two similar case areas: "*the phase of pre- metro railway line construction*" and "*the phase of post-construction*". Hereby, the effect of metro railway line projects on housing sale prices in the pre-construction of urban railway projects has been taken as the short-run effect, while the post-construction phase has been taken as the long-run effect. Using a comparative design, two case studies were selected with similar characteristics to measure the capitalisation of the metro line in general equilibrium. The findings of the paper suggest greater effects in the announcement stage (representing the short-run equilibrium effect) on value increase in the surrounding housing market than in the post-construction stage (representing the long-run equilibrium effect) of a metro railway line in İstanbul.

This paper consists of five chapters. Following this introduction, the paper reviews the literature regarding the impact of metro railway line investments on urban land and property values. It then describes the methodology of the study, including case study selection and case study

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areas. In the fourth part, the results of the model are discussed. Finally, concluding remarks with proposals for future studies are presented.

2. Theoretical background

The concern of economists surrounding urban rent values dates back to the 18th century. The basic preliminary theory for explaining differentiated land values in urban spaces was asserted by Ricardo (1963) and von Thünen (1966) on the basis of agricultural lands. David Ricardo's theory bases agricultural land rent on the differential fertility of agricultural lands. The assumption of differential rent theory is that the land in use with the lowest fertility earns no rent. Thus, it is assumed that land with greater fertility earns rent per acre that is equal to the difference between the value of its output and the value of the output of the least fertile land in use (Ricardo, 1963; Fujita, 1999; Fujita and Thisse, 2002; Mcdonald, 2007). By contrast, von Thünen's theory bases agricultural land rent on distance from the market. The land in use at the greatest distance from the market earns no rent, while other land in use earns rent equal to the cost savings in transporting the output to the market (von Thünen, 1966; Fujita, 1999; Fujita and Thisse, 2002; Mcdonald, 2007). In short, Ricardo concentrated more on fertility differences, while Thünen focused on transport-cost differentials across locations (Fujita, 1999, pp. 3-4; Fujita and Thisse, 2002, p. 63; Papageorgious and Pines, 1999, p. 4; McDonald and McMillan, 2010, p. 84).

Building on these preliminary ideas, the theory of differentiated land rent for agricultural lands was extended to urban spaces by Alonso, Mills and Muth (Muth, 1961; Alonso, 1964; Mills, 1972). Mills and Muth's model of the urban land with housing market refers to the preliminary theoretical framework employed in urban economics (Rosen, 1974; Straszheim, 1987; McMillen, 2006; Mcdonald, 2007; Spivey, 2008; Kulish et al,2011). Their related models have primarily investigated the inter-relationship regarding the trade-off between accessibility to central points for employment and the price of the residential land or housing (Muth, 1961; Mills, 1972; Mills, 2000; Mcdonald, 2007).

Numerous empirical studies have demonstrated the positive impact of rail transit on the housing market. Urban transit system investments are associated with a decrease in transportation costs and an increase in accessibility (Dube et al, 2013; Zhang and Wang, 2013; Pan et al, 2014; Wagner et al, 2017; Yen et al, 2018; Ransom, 2018; Diao et al, 2017; Sharma and Newman, 2018; Gatzlaff and Smith, 1993; Damm et al, 1980; Hiironen et al, 2015; Medda and Modelewska, 2011). Given the plethora of such examples, only a few select cases are discussed here. The first is research conducted by Dube et al. (2013) in Montreal which revealed that as a result of improved access to the Montreal Saint-Hilarie Commuter Rail Transit (CRT) Service, 115,305 housing units out of 169,286 have experienced a value uplift ranging from 0.7% to 11% based on their location to the nearest rail station. The average impact on housing values was calculated to be a 2.5% increase. The authors claim that the total value of the housing market was 44.5 billion dollars in 2009, of which 1.15 billion dollars came from access to the CRT service.

Additionally, Hiironen et al. (2015) conducted a study estimating the impact of the West Metro Line on residential apartments in Helsinki, Finland. The researchers used the hedonic price model to calculate the impact of proximity to subway stations. Their empirical results indicated that the impact of subway station proximity on residential apartment values is an average 15% increase within a 400 m radius, and 11% within an 800 m radius. The total impact is calculated as 122 million Euros from a 0–400 m radius and 193 million Euros from a 0–800 m radius.

Another study using hedonic price models, conducted by Pan et al. (2014) in Shanghai Metro in China, found that distance to rail station has a positive impact on residential property values. Models reveal that these increase approximately 1% for houses located 100 m closer to the stations.

Some researchers have included various externalities to estimate the negative impacts of being close to rapid transit stations. For instance, the noise, vibration, pollution, and crime associated with being close to a station cause housing prices to fall significantly (Mulley et al, 2018; Higgins and Kanaroglou, 2016). Similarly, houses within 300 m of a San Jose Valley Transport Authority (VTA) light rail station sold at an average $31,000 discount (Gallo and Koehler, 2014). Furthermore, a study by Skaburskis (1982) conducted in San Francisco California reveals that after the North Oakland Bay Area Rapid Transit (BART) system opened in 1972, single family houses experienced a 7% decrease at 500 ft, 3% decrease at 1,000 ft, and 1% decrease at 1,500 ft (Skaburskis, 1982).

A study conducted in Hampton Roads, Virginia, by Wagner et al. (2017) calculated the impact of the Tide Light Rail line on residential property market using the difference-in-differences model. The results demonstrate that properties experience an approximately 8% decline in sale price within 1,500 m of a rail station. This indicates that the negative effects of a station outweigh the positive accessibility benefits. The total aggregate decline in the housing market due to light rail was estimated to be $75 million.

The reason for this differentiation in the impact of rail stations among developed and developing countries might be the higher level of welfare in developed countries. Furthermore, the greater dependence of societies in developing countries on mass transit for daily commuting (in order to minimize their transportation costs) means they may prefer to live closer to urban mass transit systems.

In addition to the general literature on the effects of urban railway projects on housing prices, specific studies have also been conducted on ***the effects of urban railway projects on housing prices with regard to the different stages of these projects***. To illustrate, a study investigating the impact of the Epping-Chatswood rail link in North-west Sydney conducted by Ge et al. (2012) concluded that, from the time the metro railway line project was announced to the start of the construction work two years later, housing prices increased by approximately 17%. After construction started, the increase continued but at a diminishing rate. Durng some periods of construction, the values decreased. Finally, when construction approached completion, the area started to report higher gains with increasing rates. This reveals that the housing market responds differently to the various stages of the metro railway line project (Ge et al., 2012).

Another study also referred to the different stages of a railway project, mainly before construction and after construction. Herein, it was asserted that to quantify the effect of the construction of a metro railway line on the price of a given property, one would have to compare the new price with the price that would have been obtained if the metro railway line had not been built. This is an imagined counterfactual situation as it is not possible to observe the same housing unit under both conditions (Agostini and Palmucci, 2008). In this study, comparisons between different housing units and the related estimations were realized using the *treatment effects model*.

According to another study conducted by Yen et al. (2018) in Queensland, Australia, property prices in the catchment areas (800 m) tend to increase after a project is announced. Afterwards, in response to the financial commitment realized by the government, the highest increase occurs. During the construction and operation period the related increase continues, but at a lower rate.

Furthermore, a study conducted by Pan et al. (2014) reported that it takes time for residential property values to internalize the increase. The calculations in 2007 and 2010 produced different results in Houston and Shanghai. In 2007 the authors used both Maximum Likelihood Ratio (MLR) and Ordinary Least Squares (OLS) models and calculated that access to a rail station has negative impacts; however, the same models reported positive figures in the same area in 2010.

The findings of another notable study by Duncan (2011), which employed a cross-sectional hedonic price model in the case of San Diego, California, revealed that a condo in a well-integrated pedestrian environment and located near a station (TOD: Transit Oriented Development) has a significantly higher value than a condo in a similar neighborhood that is not located near a station. By contrast, a condo in a less walkable residential neighborhood, which is located near a park and ride station (TAD: Transit Adjacent Development) tends to have less value than a condo in a similar neighborhood that is not located near a station (Duncan, 2011). Thus, the change in accessibility–especially with regard to the pedestrians–throughout the different stages of TOD (involving railway investments) will affect housing prices in different ways. In this sense, having well oriented pedestrian links increases the level of accessibility and hence the sales value of station-proximate locations should also increase (Duncan, 2011). In this sense, the short-run effect of any urban railway system investment, which makes the related environment more pedestrian-friendly (easily and securely walkable), will lead to an increase in housing sale prices. Conversely, the related short-run effect of such an investment, which makes the environment more automobile dependent (around the stations), will lead to a fall in housing prices (Duncan, 2011).

Another study conducted in Canada investigated the effects of urban railway projects on housing prices with reference to different stages; namely, before the announcement of the urban railway line confirmation of the project, during construction, and after completion of construction (Bagheri et al., 2012). Multiple sale analyses were conducted as the related data was available for the years 2000 and 2012. Furthermore, the distance parameter was stratified according to 0.5 km, 1 km, and 2 km radiuses (Bagheri et al., 2012). According to the empirical findings of both studies, the announcement of the railway projects causes a higher rise in housing prices when compared to the post-construction (operation) stages (Agostini and Palmucci, 2008; Bagheri et al., 2012).

Another study was conducted in Tehran, Iran, to measure the impact of the metro railway line system on residential property values by performing a comparative analysis between high- and low-income neighborhoods. The results revealed a high value increase in low-income neighborhoods, while in high-income neighborhoods a negative treatment effect was calculated for residential properties (Forouhar and Hasankhani, 2018). This study provides a basis for making a comparison between developed and developing countries as this classification is highly related to the economic conditions of local residents. Another study conducted by Nelson (1992) concluded that income levels affect the rate of housing value increases differently. The study revealed that property values increased by approximately US $1,045 for every 30 m closer to the East Line in Atlanta in low income neighborhoods. By contrast, property values decreased by US$ 965 for high income neighborhoods. This reveals another effect of income levels on housing values along the urban railway corridors (Nelson, 1992).

In light of all these findings, this paper aimed to identify during which stage of a metro railway line project the housing market responds with rising values in the case of İstanbul, Turkey. Specifically, a comparison is made of the effect of metro railway line investments on housing prices with regard to the two main stages of a related project: the announcement (pre-construction) stage, and the post-construction (operation) stage, with reference to two similar case areas. It aimed to show whether the effect of a metro railway line project on housing sale prices decreases after construction when compared to its announcement stage. Hereby, it will be possible to examine the trade-off between changes in levels of accessibility to urban transportation infrastructure and changes in housing sale prices for the selected case areas. The first area has an operating metro railway line whilst the second has a metro railway line project which is currently under construction. Because it is not possible to compare property values before and after the arrival of the same metro railway line with the data available, this study first aimed to reveal that these areas are to a large extent identical in the socio-economic characteristics of their residents and the attributes of the housing units. A ***before and after analysis*** was then conducted on the effect of the different stages of metro railway line investments on housing sale prices. This will show for İstanbul whether a metro railway line project in the planning stage, or under construction, has a higher impact on the housing market than a metro railway line project under operation (although more data will be needed).

Finally, it is important to highlight that the study of the cross relations between housing prices, labor markets, and the cost of commuting is quite complex. In urban scenarios–especially with regard to the big metropolitan areas–housing sale prices are thought to be related to the commuting distance (or time of commuting) and to the level of wages in labor markets (Guirao, Casado-Sanz, and Campa, 2020). Guirao, Casado-Sanz and Campa (2020) assert that the differences in unemployment rates and wage levels explicitly direct the labour flow especially with regard to the transportation infrastructure taking the railway infrastructure into the core. They conducted their analysis by taking the independent factors such as wage differentials, housing rental prices, and population into account in order to measure the effect of railway infrastructure of different time periods (the short-run and the long-run) on labour mobility on the regional/sub-regional scale (Hincks and Wong, 2010; Haas and Osland, 2014; Guirao, Casado-Sanz, and Campa, 2020). A similar methodological concept was implemented in this study by transferring the spatial scale from the regional/sub-regional level to the urban districts level with regard to the two selected metro railway lines. Also, the dependent variable in our case is housing sale prices, while that of Hincks and Wong (2010), Haas and Osland (2014), and Guirao, Casado-Sanz, and Campa (2020) was labour mobility, but with similar independent factors taken into account in their analyses and discussions.

One more vital difference in our study is that unlike analyses that are performed by focusing on housing rental prices under the assumption of flexible housing market demand (Himmelberg, Mayer, and Sinai, 2005; Guirao, Casado-Sanz, and Campa, 2020), our analysis uses the housing sale price under the assumption of presumable housing market demand. This is because the user cost dynamics of Turkey are notably different from the cases asserted in the related studies. Therefore, instead of detailed discussions on whether the sale prices or rental prices are more reliable in the housing market in the provinces/regions of different countries, our study confines itself to making a preliminary assumption of inflexible housing market demand so as to derive its axioms.

3. Data set and methodology

In this part, the study area located in İstanbul is described. Secondly, data and materials used for the related analyses are explained. Thirdly, the model variables with the related model structure are outlined in accordance with the research question.

3.1. Study area Definition

As a developing country, Turkey has been selected to investigate the impact of metro railway line project stages on the housing market. İstanbul is the city where most urban railway projects are initiated, due to high mobility needs. For this study, two metro railway line corridors were selected. One is the Ataköy- İkitelli metro railway line, which has been announced and for which construction has started but is not yet operational. This is the main case (MC) in this study. The other project is the Esenler- Kirazlı metro railway line which is currently operational; this line is regarded as the control case (CC). The study area selected as a pre-construction case, namely the Ataköy-İkitelli metro railway line corridor, was chosen among all urban railway projects in İstanbul based on the following criteria. The first criterion was that it had to be a metro railway line project; thus monorail and tramway lines were eliminated from the data set. The other criterion was that it should be between 10 km and 20 km in length. The length of this corridor is 13 km with 12 stations. In this respect, the average length of metro railway line projects in İstanbul is approximately 19 km, and because it is very difficult to analyze a very long corridor and a short corridor would not provide enough data, this corridor was selected as the main case. The other criterion was the population of districts through which the metro railway lines passes and average population served per km. The control case selected was the Esenler-Kirazlı metro railway line. The reason for selecting this corridor was that it is very close to the main case, but does not intersect with it. They both pass through districts and neighborhoods with similar characteristics. Based on a similarity check, these two case study areas have similar characteristics in terms of population and population density, average age, schooling years, university education, and household size. Also, they have similar housing characteristics such as age, size, and number of rooms/bathrooms of the apartments. There are five stations on the Esenler-Kirazlı metro railway line and the route is 5.8 km long. The black line (directed towards North-South) in Fig. 1 depicts the location of the main case in the proposed urban railway network for İstanbul for 2024 (IMM, 2020).

The West-East directed bold red line in the figure above depicts the control case, which is currently operational. It is an extension of the Yeni Kapi- Atatürk Airport metro railway line, which is indicated in the ***reverse v*** shaped green line in the figure. These lines intersect at Yenibosna station, which is indicated by the red circle. Furthermore, it should be pointed out that there is no single Central Business District (CBD) in İstanbul, so the distance to CBD cannot be discussed; however, the locations of rail corridors and their relationship with each other can be seen in the figure. When the surrounded lines are constructed, these two lines will also have a transfer station.

In this study, another important parameter is the time line of these two projects. The control case went to tender on 2_{nd}July 2003, which refers to the official announcement of the project to the public. The contractor who won the bid started construction work on 14th October 2005. The critical time was between the years 2003 and 2005, because once construction starts, the market value of such areas tend to have a decreasing value curve due to construction site disturbance. The project was completed and commenced operation on 14th June 2013. There was a time gap of 10 years between announcement and commencement of operations, during which time there would have inevitably been some fluctuations in the housing market. This survey was conducted on 1st April 2017**.** Similarly, the timeline data was gathered for the main case study area, in which the metro railway line project went to tender on 10_{th}August 2015 and construction began on 15th February 2016. The related construction work is still ongoing and the project is expected to be completed in 2023.

3.2. Data and materials

Two similar case study areas have been selected to examine the sale prices of housing units in the same area throughout two stages of a metro railway line project; namely, announcement stage (pre-construction, which refers to short-run) and post-construction stage (which refers to long-run). However, the latter is not feasible in the case of İstanbul due to the lack of relevant databases. As explained in the ***Study Area Definition*** part of the paper, these case areas are the Ataköy-İkitelli metro railway line, which is in the announcement stage, while the second is the Esenler-Kirazlı metro railway line, which is currently in operation. Herein, the second line is is the control case (CC), while the other has been defined as the main case (MC). Thus, the first case represents the pre-construction stage of the metro railway line project (announcement stage) with reference to a period called the short-run period, beginning with the announcement of the project; and the second represents the post-construction stage, with reference to the long-run period of a project encompassing construction and operation of the project **(see** Fig. 2**).**

Subsequently, the similarities of these case areas are tested in two main categories: the socio-economic characteristics and the housing attributes of each case area. As discussed in the ***Designation of the Model Structure*** part of the paper, socio-economic characteristics are emblematized by the parameters of population, average age, average schooling years, university graduation degree, and household size of each case area. Additionally, the housing attributes of these two case areas are represented by the distance to the nearest metro railway line station, age of the building, size of the housing unit, number of rooms, number of bathrooms, type of toilet, corner location, cardinal direction, and the dummy variable with reference to the elevator system of the houses.

The sample data for this study comes from on-site surveys conducted by the survey teams consisting of graduate students and real estate agents working together in 500-metre radius circular zones **(see** Fig. 3**).** This 500 m radius is derived from Turkish Zoning Law. The optimal walking distance is defined as 500 m (Turkish Zoning Law (2020), Suplemantary Article 8, 14/2/2020-7221/12). One of the most important constraints on this study is the lack of official records for real estate selling prices in Turkey. In general, the selling price of real estates are registered as less than their actual selling price at Land Office, thus the selling price data is collected via real estate agents. To calculate the value impact of proximity to metro railway line stations on housing sale prices, a questionnaire survey was conducted with real estate agents working around the stations in the first case study area. Details on housing sale prices (which are recorded by the related real estate agents in Turkish Lira by the year 2017) and their attributes were collected. For the five stations in the first case, 665 questionnaires were collected in total. The same procedure was then implemented for the second case study area to calculate the impact of anticipated metro railway line-operation on housing prices. In the second area, 1,151 questionnaires were administered to real estate agents.

In the survey, the aim was to obtain as many complete questionnaires as possible. However, The number of real estate agents, and the number of apartments in their housing portfolio, ultimately determined the number of questionnaires. The sufficiency of the related sample size of each case area can explicitly be justified by the central limit theorem (Hill, 1998; Wilson, Voorhis, and Morgan, 2007; Hogg, Tanis, and Zimmerman, 2014). In other words, each of the twelve variables (Table 1) asserted in the related case study areas can explicitly be assumed to be Gaussian distributed, as each sample size is many times greater than the minimum treshold value of 30. In addition, the minimum required sample size is determined by the confidence level assigned by the researcher and the variance of the related variables (Hill, 1998; Wilson, Voorhis, and Morgan, 2007; Hogg et al., 2014).To illustrate, by taking a 95% confidence level–denoting a 5% error–into account and by calculating the variance of the housing sale prices in each case area, it is clear that at least 650 observations are needed for each case area[1], which is fewer than the actual sample sizes of 665 and 1,151, respectively for each case area.

Fig. 4 depicts the location of the selected case studies in İstanbul. They are on the European Side.

The circular zones for each station are presented in Fig. 5**.**

In the related case study areas, twelve variables were defined with regard to housing units, as indicated in Table 1.

3.3. Designation of the model structure

To measure the impact of proximity to a urban railway station on housing prices, the hedonic price model was applied. According to Rosen (1974), this model assumes that goods are typically sold as a package of self-existing features. The price of a house is the sum of all its inherent prices estimated through a regression analysis (Rosen, 1974; Ge et al., 2012).

Furthermore, Herath and Maier (2010) state that the rationale underpinning this model is that properties are characterized by their combined attributes, thus the value of a property can be calculated by

[1] $n = z^2\, \sigma^2/e^2$, where n = sample size, z = z score of the assigned confidence level (95%), σ^2 is variance of the housing sale price, e = error that is automatically assigned by the confidence level (Hill, 1998; Wilson, Voorhis, and Morgan, 2007; Hogg, Tanis, and Zimmerman, 2014).

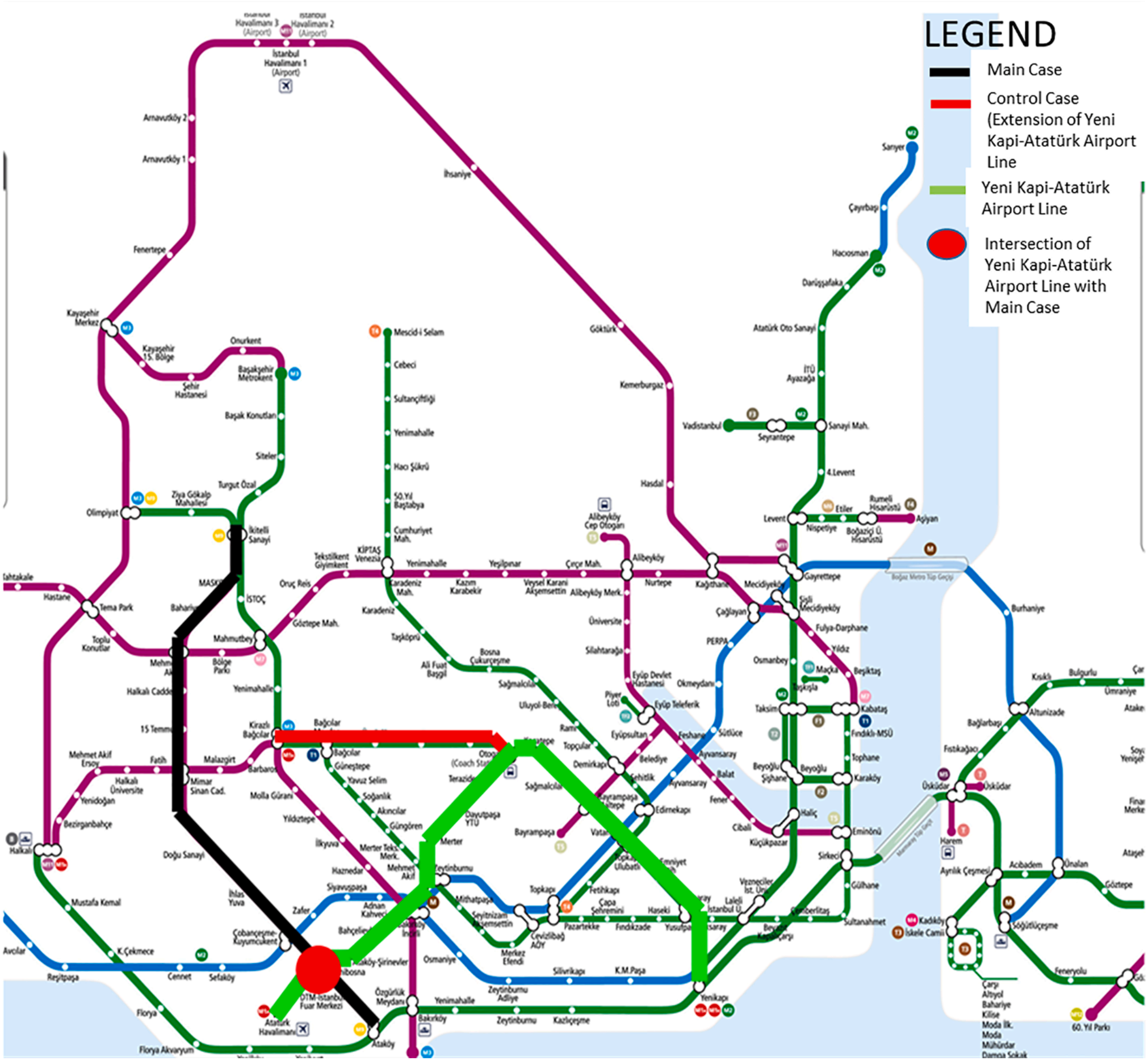

Fig. 1. Locations of two selected case studies and their connections to each other.

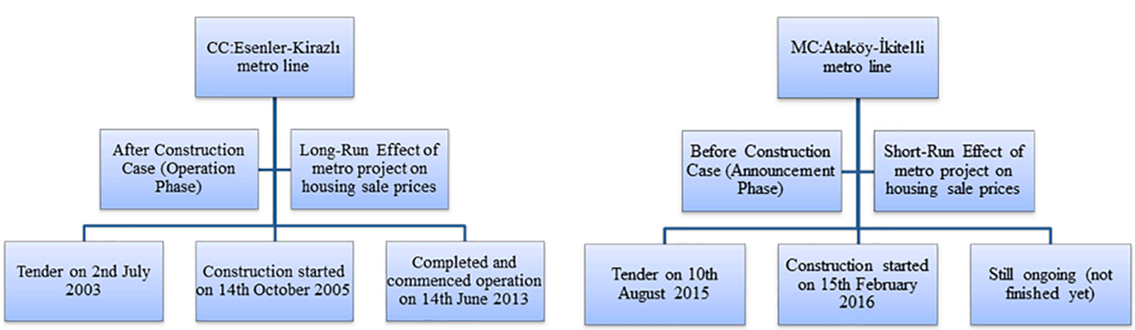

Fig. 2. Time phases of the selected two metro railway line projects.

suming the estimated values of its separate attributes. Thus, a classical hedonic model of housing prices is linearly structured based on the explanatory variables, which can be categorised into three main headings: attributes of the housing units, neighborhood characteristics, and location attributes. Thus, the distance of the housing unit to the nearest metro railway line station was added as another explanatory variable in the model. The aim was to derive the marginal effect of the distance on housing sale prices, which can be defined as a proxy for the effect of a metro railway line project on housing sale prices.

A hedonic price model was the run for each area (main case area refers to the pre-construction stage and the control case area refers to the post-construction stage of the related projects) with twelve housing attributes, in which the dependent variable was the sale price of the property, whilst the explanatory variables were distance to the metro

Fig. 3. The method for defining the circular zones.

Table 1
Variable definition and name.

Variable Definition	Variable Name
Distance of the housing unit to the nearest metro railway line station (meters)	distance
Floor area of the housing unit (square meters)	size
Price of property (selling price of housing unit in Turkish Lira)	price
Age of building (years)	age
Number of rooms in housing unit	rooms
Number of bathrooms in housing unit	baths
Dummy variable describing the type of toilet in housing unit with reference to alaturka type or otherwise (1: if alaturka, 0: otherwise).	alaturka
Dummy variable indicating whether thebuilding is located at a corner facade (1: iflocated at a corner, 0: otherwise).	corner
Dummy variable indicating whether thehousing unit is located on a west facade (1: if located on west, 0:otherwise).	west
Dummy variable indicating whether the housing unit is located on a north facade (1: if located on west, 0: otherwise).	north
Dummy variable indicating whether thehousing unit is located on a south facade or not (1: if located on west, 0: otherwise).	south
Dummy variable indicating whether thehousing unit has an elevator (1: if it has, 0: otherwise).	elevator

railway line station, size and age of the apartment, number of rooms and bathrooms, existence of an alaturka toilette, existence of an elevator, and the direction of the apartment facade. The related model structure can be represented by the following equation:

$$Y_i = \alpha_i + \delta_{ij}\ x\ X_{i1} + \delta_{ij}\ xX_{i2} + \mu_i \quad (1)$$

where $\boldsymbol{Y_i}$ represents the housing prices for the case area i; $\boldsymbol{X_{i1}}$ represents the housing attributes such as building age, size of the housing unit, number of rooms of the housing unit, number of bathrooms, dummy variable for the type of the toilet, and dummy variable for elevators inside the building; $\boldsymbol{X_{i2}}$ represents the local facilities of the housing units, such as distance of the building to the nearest metro railway line station, and facades of the units (such as corner, South, West and North) for the area i; $\mathfrak{z}_i$ is the regression constant for the model referring to the area i; $\boldsymbol{\mu_i}$ is the error of the model for the area i; and $\boldsymbol{i}$ stands for the notation of the related case areas, in which $\mathbf{i} = 1$ represents the area of the metro railway line investment in the post-construction stage (control case), whilst $\mathbf{i} = 2$ represents the area of the metro railway line investment in the pre-construction stage (main case).

Further to the designation of the model structures, the aim was to compare the associated marginal impacts of the distance variable as a proxy of the impact of the metro railway line project on housing sale prices for two different cases. Hereby, it aimed to provide empirical support for the assertion that in comparison to the post-construction phase of the metro railway line investment, the impact on housing prices is greater when the metro investment is in its speculation phase (pre-construction stage).

3.3.1. Similarity check for the selected areas

There are two possible ways to compare the impact of different stages of metro railway line projects on housing sale prices. The first is to collect data on sale prices of housing units in the same area over the years in reference to pre-construction and post-construction stages of these projects. The second way is to assign two similar case areas, one referring to the post- construction stage, and the other to the pre-

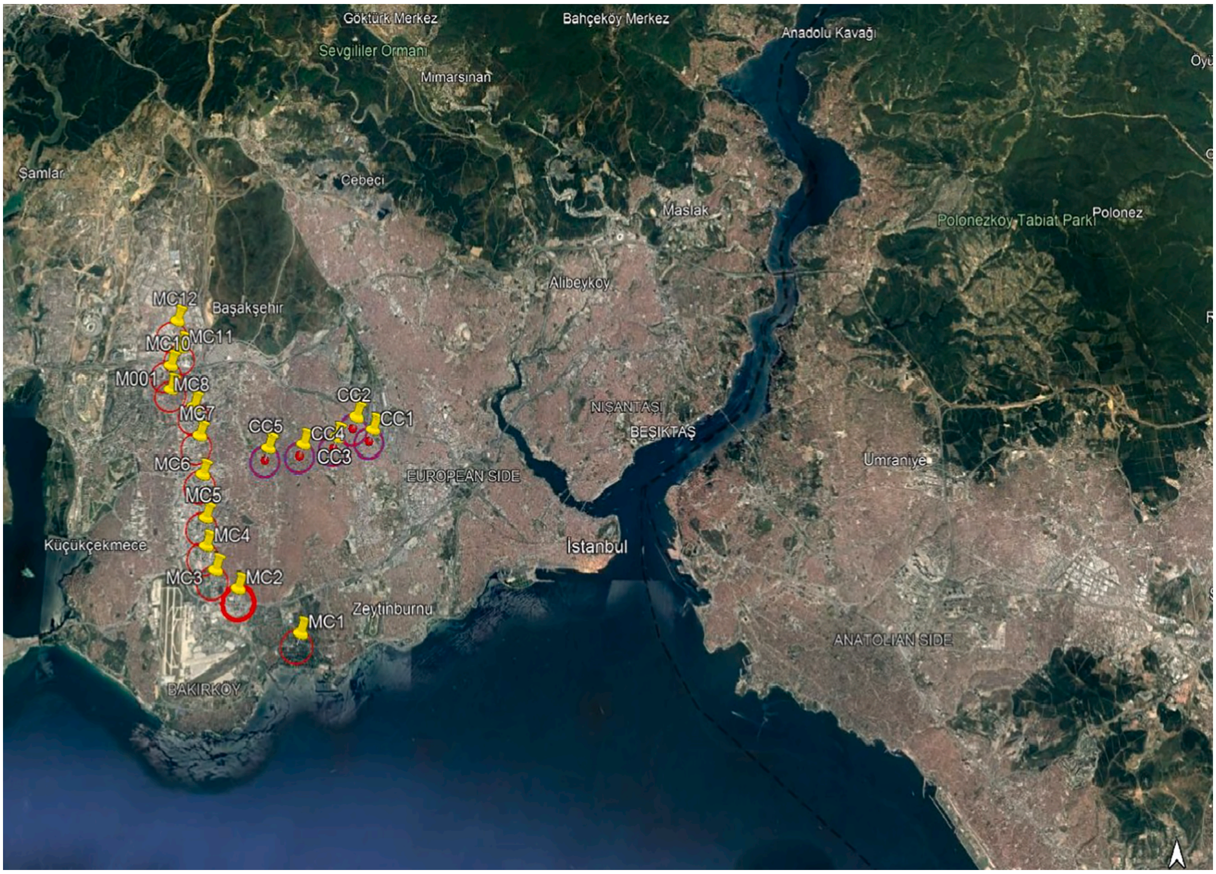

Fig. 4. Location of Main Case and Control Case in İstanbul.

construction stage of the related projects (Angrist and Imbens, 1994; Agostini and Palmucci, 2008). Because the related data in Turkey is limited, the second option was used. The similarities of these case areas were checked in two main categories, namely the socio-economic characteristics and the housing attributes of each case area. To be certain, statistical tests were conducted. Herein, the related socio-economic characteristics are represented by population, average age, average schooling years, university graduation degree, and household size of each case area, as indicated in Fig. 6. In addition, the housing attributes of these two case areas were also tested for similarities **(see** Fig. 6**)**. A paired *t*-test was conducted for the similarity check. A two-sided hypothesis test was conducted with the null hypothesis asserting that the related means of the socio-economic factors and housing attributes for the two case areas are the same with regard to related factors versus the alternative hypothesis which asserts just the opposite**.** Herein, if the critiqued t-value of the related confidence level is less than that calculated, the null hypothesis is rejected (Hickman and Hilton, 1971; Sproull, 1988; Kirk et al., 1990; Mosteller, et al. 2013; Çubukçu, 2015).

3.3.2. Model comparison after similarity check

As asserted in the designation of the model structure, Eq. (1) reveals that the housing sale price, as the dependent variable, is a function of the vectors of the housing properties and vector of local facilities of the related housing unit. This equation can be separated into two: one for the area before the metro railway line investment (announcement stage) and the other for the area after construction (operational stage) of the metro railway line investment. If both housing attributes with the related local facilities and socio-economic characteristics of these two areas do not differ significantly, then the separation for the Eq. (1) can be formulated as follows:

$$\begin{aligned} &Housing.Price.1(in.the.area.during.the.announcement.stage.in.that.i=1)\\ &=\alpha_1\ +\delta_{11}\ \times(Vector.of.Housing.Attributes)+\delta_{12}\times(Locational.Facilities)+\mu_1 \end{aligned}$$

$$\begin{aligned} &Housing.Price.2(in.the.area.after.the.construction/operation.stage.in.that.i=2)\\ &=\alpha_2\ +\delta_{21}\ \times(Vector.of.Housing.Attributes)+\delta_{22}\times(Locational.Facilities)+\mu_2 \end{aligned} \quad (2)$$

Based on the results of Eq. (2), it is possible to derive the related model coefficients and make a comparison between them. The coefficient of the factor called distance is expected to determine the impact of the metro railway line investments on housing sale prices.

In addition to the model structures, based on the hedonic price index model asserted above (Eq. (2)), the Average Treatment Effects (ATE) model was also run to demonstrate once more the impact of the metro railway line investment announcement on housing sale prices in the two case areas.

The logic of the ATE model is based on assessing the average impact of any treatment. In this sense, the stages of the metro railway line investments can be asserted as a kind of treatment, in that if the investment is in its pre-construction (announcement) stage, there has not yet been any treatment. If the investment is in its post-construction stage, the treatment of the metro railway line operation can be defined. Thus, a treatment variable is asserted whereby if the metro railway line is constructed and the operation has begun (with reference to the post-construction stage), then it takes on the value 1, otherwise (with reference to the pre-construction stage) it takes on the value 0. As such, estimating the coefficient of the treatment variable explicitly gives the average difference in impact on housing sale prices with regard to the pre-construction phase and post-construction phase of the metro railway line investments. In the ATE model structure, if ***E[·]*** denotes the mathematical expectation symbol; then with reference to the continuous

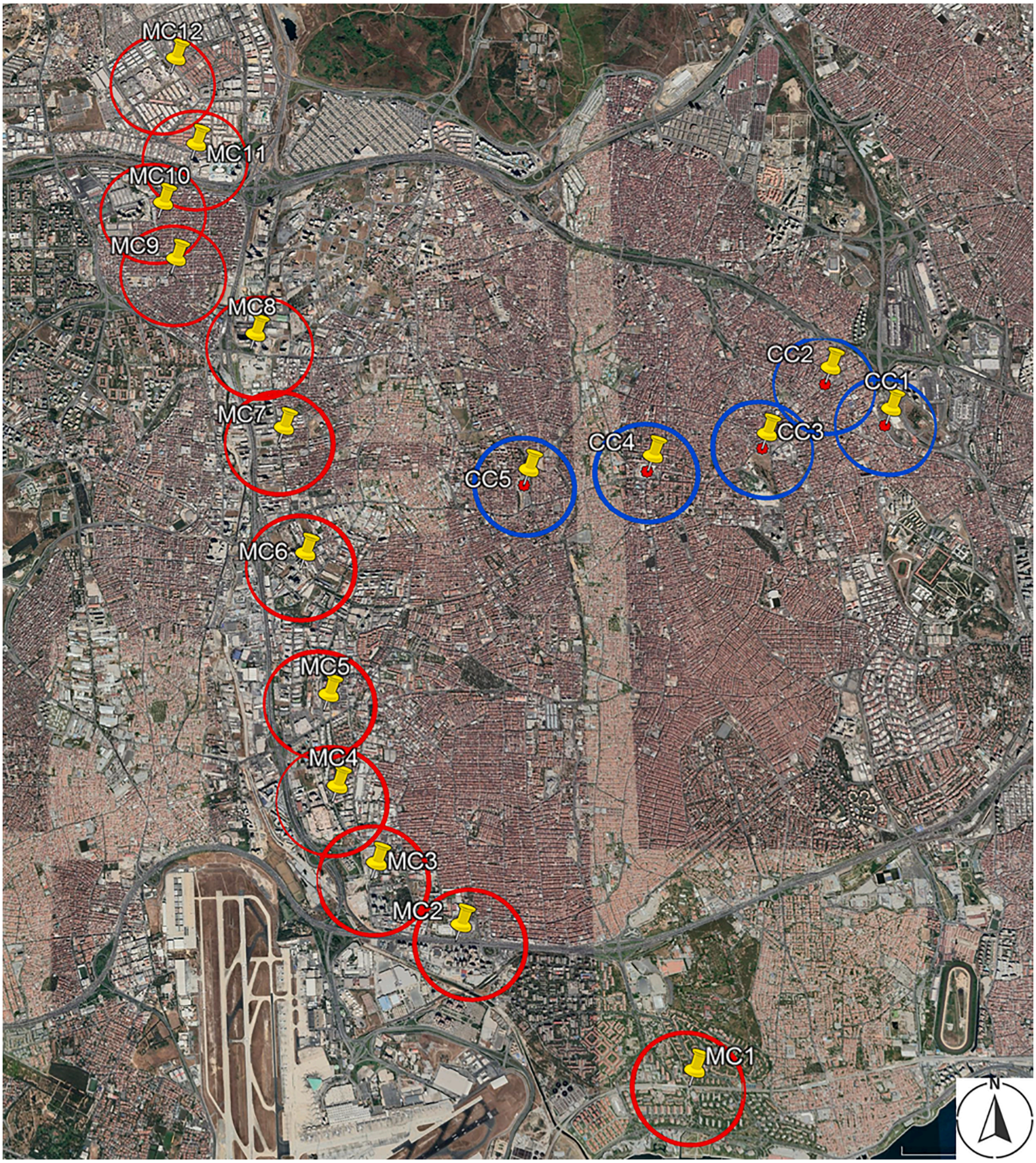

Fig. 5. Circular zones for each case study area and their stations.

random variables, such as the housing prices of each case area (Y_i), it can be represented by;

$$E[Y_i] = \int yf(y)dy \tag{3}$$

where ***f(y)*** is the density function of Y_i (Ashenfelter, 1978; Rosenbaum and Rubin, 1983; Dehejia and Wahba, 1999; Cameron and Trivedi, 2005). By the law of large numbers, sample averages begin to converge to population averages so that ***E[·]*** gives the sample average in large samples. The two most widely studied average causal effects are the average treatment effect E[Y1i − Y0i], and the Average Treatment Effect on the Treated (ATET), $E[Y_{1i} - Y_{0i}| D_i = 1]$ where D_i refers to the dummy variable standing for treatment (Ashenfelter, 1978; Rosenbaum and Rubin, 1983; Dehejia and Wahba, 1999; Cameron and Trivedi, 2005). Herein, the ATET can be rewritten as:

$$E[Y_{1i} - Y_{0i}|D_i = 1] = E[Y_{1j}|D_j = 1] - E[Y_{0i}|D_i = 1] \tag{4}$$

This expression highlights the counter-factual nature of a causal effect. The first term is the average increase in housing prices in the population of housing units located in the area with a metro railway line station (post-construction stage). This is a potentially observable quantity. The second is the average increase in the housing prices in the population of housing units located in the area without a metro railway line station (before construction stage). This cannot be observed, although a control group or econometric modeling strategy may provide a consistent estimate.

However, unlike regression, treatment effects are constructed by matching individuals with the same covariates instead of a linear model for the effect of covariates. The key identifying assumption is that the effect of covariates on Y0i need not be linear. Instead, the conditional

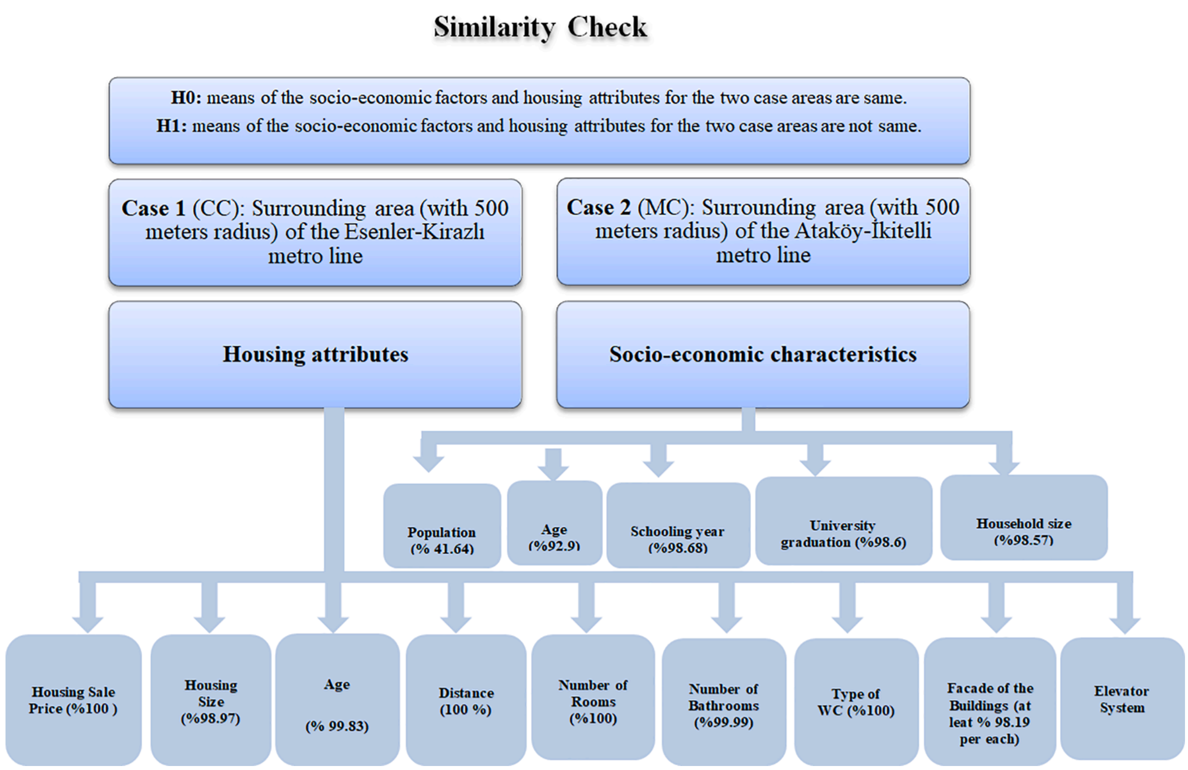

Fig. 6. The parameters of the similarity check for the two case areas (the percentages in parenthesis represents the similarity ratio of each parameter in the analyses).

independence assumption becomes:

$$E[Y_{ji}\ |X_i, D_i]\ = E[Y_{ji}\ |X_i],\ for\_j = 0, 1 \tag{5}$$

This implies:

$$E[Y_{1i} - Y_{0i}\ |D_i\ = 1]\ =\ E\{E[Y_{1i}\ |X_i, D_i\ = 1]\ - -[Y_{0i}\ |X_i, D_i = 1]\ |D_i\ = 1\} = \ E\{E[Y_{1i}|X_i, D_i\ = 1]\ - -[Y_{0i}\ |X_i, D_i\ = 0]\ |D_i\ = 1\} \tag{6}$$

Likewise:

$$E[Y_{1i} - Y_{0i}] = E\{E[Y_{1i}\ |X_i, D_i\ = 1]\ - -[Y_{0i}\ |X_i, D_i\ = 0]\,\} \tag{7}$$

(Ashenfelter, 1978; Rosenbaum and Rubin, 1983; Dehejia and Wahba, 1999; Cameron and Trivedi, 2005). Because these expressions involve observable quantities, it is straightforward to construct consistent estimators from their sample analogs.

4. Model results and discussions

According to the results of similarity checks for these two case areas, the housing properties of latter are almost the same within a confidence level of at least 98%. Furthermore, the socio-economic characteristics of these two case areas are also almost the same with a confidence level of at least 93%, except for the population. Thus, these two case areas exhibit statistically significant similar patterns in terms of their housing attributes (and thus sales prices and their socioeconomic characteristics).

Using these similarity checks, it was possible to compare the impact of different stages of the metro railway line investment in the two case areas as if they were the same area going through both pre-construction and post-construction stages.

In accordance with the research question, the marginal impact of distance of a housing unit to the nearest metro railway line station on the housing sale price was investigated for each case area. Accordingly, the related housing attributes were the age of the building, size of the housing unit, number of rooms, number of baths, and type of toilet in the housing unit. In addition, the local facilities of the housing units, namely distance of the housing unit to the nearest metro railway line station, a dummy variable called corner denoting whether the building unit is located at a corner, dummy variable west indicating whether the housing unit faces west, dummy variable north referring to whether the housing unit faces north, and dummy variable south indicating that whether the housing unit is located on the south facade. Finally, the dummy variable elevator denoting whether there is an elevator in the building was defined as another explanatory variable of the housing price. Based on these factors, the hedonic price model by the ordinary least squares regression model structure was designated as an extended version of Eq. (2):

$$\begin{aligned} Price_i = \alpha_i + \ \beta_{1i}x(metro\_dummy)\ + \ \beta_{2i}x(distance)\ + \ \beta_{3i}x(age)\ + \ \beta_{4i}x(size)\ + \ \beta_{5i}x(rooms) \\ +\beta_{6i}x(baths)\ + \ \beta_{7i}x(alaturka)\ + \ \beta_{8i}x(corner)\ + \ \beta_{9i}x(south)\ + \ \beta_{10i}x(west)\ + \ \beta_{11i}x(north) \\ +\beta_{12i}x(elevator)\ + \ \mu_i \end{aligned} \tag{8}$$

where i stands for the related case area that is modeled. Eq. (8) is called the Ordinary Least Squares (OLS) model and was used to test our hypothesis that "***the prices of the housing units are affected much more in the announcement phase of the metro railway line projects when compared to those of the construction and operation phase***". In this context, there are two possible methods. The first method, which is not feasible in Turkey due to the unavailability of data, is to collect all required data on the sale prices of housing units in the same area in different time periods. After collecting and compiling all the related data, the impact on the sale prices of the housing units is compared. However, even though the results would be precise, such data collection is almost impossible in developing countries like Turkey, as this data is recorded. Thus, the second method was adopted, in which the impact of the two phases of two different metro railway line projects on housing prices in their separate but similar case areas was assessed. If the associated local facilities and socio-economic characteristics of these two areas did not differ significantly according to paired samples t–tests, then the separation for Eq. (2) can be formulated as:

$$Price\ \left(of\ announcement\ stage\ with\ reference\ to\ the\ 2^{nd} case\ study\ area\right) = \alpha' + b_1x(distance) + \text{ƀ}_2x(age) + \text{ƀ}_3x(size) + \text{ƀ}_4x(rooms) + \text{ƀ}_5x(\text{ƀ}aths) + \text{ƀ}_6x(alaturka) + b_7x(corner) + b_8x(south) + b_9x(west) + \text{ƀ}_{10}x(north) + \text{ƀ}_{11}x(elevator)\ b\ \mu' \tag{9}$$

$$Price\ (of\ post\ construction/operation\ stage\ with\ reference\ to\ the\ 1^{st} case\ study\ area) = \alpha'' + \beta_1'x(distance) + \beta_2'x(age) + \beta_3'x(size) + \beta_4'x(rooms) + \beta_5'x(baths) + \beta_6'x(alaturka) + \beta_7'x(corner) + \beta_8'x(south) + \beta_9'x(west) + \beta_{10}'x(north) + \beta_{11}'x(elevator) + \mu'' \tag{10}$$

According to the results of the OLS-1 model, the coefficients of the variables that refer to the facades of the buildings, such as corner, West, South, and North, were not statistically significant at the 95% confidence level **(see Table 2)**. All remaining explanatory variables were statistically significant at an almost 100% confidence level. Thus, the statistically significant factors affecting the housing prices are bathroom, elevator, alaturka toilet, rooms, and age. Thus, the housing attributes, namely the number of baths in the housing units, dummy variable denoting whether there is an elevator system in the building, the type of the toilet in the housing unit, number of rooms in the housing unit, and age of the building are the leading significant factors affecting the housing prices according to the OLS-1 model.

Furthermore, the assertion that "***the closer the housing unit is to the nearest metro railway line station, the higher the price of this housing unit***" has explicitly been verified according to this model. Herein, a housing unit which is one meter closer to the nearest metro railway line station will have a 90.98 TL higher price. Therefore, in the case of the Atakoy/Ikitelli metro railway line, the announcement of the project affects housing sale prices by 9.098 TL per 100 m of distance. This finding constitutes explicit evidence that speculation in housing prices due to metro railway line investments is significant in Turkey as a developing country.

Conversely, according to the results of the OLS-2 model (equation (10)), the coefficients of all the variables, except for West and North, were statistically significant at a 96% confidence level at least. The coefficients of North and West were significant at only 81.9% and 92.7% confidence levels, respectively **(see Table 2).** The leading factors affecting housing prices of the area in the post-construction (operation) stage of the metro railway line project are therefore corner, baths, elevator, South, and rooms. Notably, factors such as the facades of the buildings, Corner, and South are leading significant factors for the OLS-2 model, which were nonsignificant in the OLS-1 model. Conversely, factors such as number of baths in the housing unit, the dummy variable indicating whether there is an elevator system in the building, and number of rooms of the housing units are prominent factors affecting housing prices in OLS-2 that were also significant in the previous model (OLS-1). Furthermore, the coefficient of distance is 43.44, which reveals that a post-construction stage that brings a housing unit 100 m closer to the closest metro railway line station results in an increase of 4,344 TL in housing prices in the case of the Esenler/Kirazli metro railway line.

In light of the findings, the impact of the announcement of a metro railway line project on housing prices increases more than twofold when compared to that in the post-construction stage. In other words, in most developing countries like Turkey, the speculation impact of declaring a metro railway line investment on housing prices would be much higher than the impact of the construction and operation of a metro railway line investment. However, further data are needed to verify this.

Finally, in addition to the OLS model structures, the average treatment effect model provides an opportunity for researchers to compare the average change over time in the effect of metro railway line investment on sale prices of housing units for the treatment group, compared with the average change over time for the control group. According to the average treatment effect model, the speculative effect of the announcement of metro railway line projects is much higher than that of the construction of metro railway line projects. The average difference is equal to 86,756.37 TL for a housing unit in the cases of the Esenler/Kirazli and Atakoy/Ikitelli metro railway lines in İstanbul. Furthermore, for the district which is in the pre-construction (announcement) stage of the metro railway line, the average impact of

Table 2
OLS-1 (Equation (9)) and OLS-2 (Equation (10)) Results.

OLS-1 Model			**OLS-2 Model**		
Variable	**Coefficient**	**t**	**Variable**	**Coefficient**	**t**
distance	−90.98056	−3.63	**distance**	−43.44265	−2.54
age	5,533.7	9.36	**age**	−3,844.612	−15.88
size	3,260.297	11.55	**size**	616.833	3.89
rooms	−44,354.68	−4.78	**rooms**	1,8461.1	3.59
baths	72,979.29	4.52	**bathroom**	23,519.68	3.53
alaturka	−235,621.2	−20.14	**alaturka**	14,449.61	3.01
corner	−22,787.72	−1.16	**corner**	−24,736.05	−2.29
south	−34,304.23	−1.66	**south**	−21,784.47	−2.09
west	30,624.82	1.25	**west**	−20,410.84	−1.79
north	−35,144.13	−1.69	**north**	−18,845.78	−1.34
elevator	74,716.7	6.15	**elevator**	21,964.14	4.55
constant	197,746.7	7.06	**constant**	168,446.2	11.29
Summary Measures for OLS-1			**Summary Measures for OLS-2**		
Number of observations		1,151	**Number of observations**		665
F(11, 1139)		106.18	**F(11, 653)**		79.57
Prob > F		0.0000	**Prob > F**		0.0000
R-squared		0.5063	**R-squared**		0.5727
Adj R-squared		0.5015	**Adj R-squared**		0.5655
Root MSE		1.6e + 05	**Root MSE**		46,042

Table 3
Average Treatment Effect with Regression Adjustment (ra) Model Results.

Dependent Variable = Price	Robust Coefficient	Standard Error	z	[95% Conf. Interval]	
ATE					
metro_dummy **(1 vs 0)**	**−86,756.37**	7,238.478	−11.99	−100,943.5	−72,569.22
metro_dummy **0**	363,767	6,265.624	58.06	351486.6	376,047.4

the distance parameter.

on housing prices is 363,767.0 TL **(see Table 3)**.

5. Conclusion and outlook

In contrast to developed countries, the announcement of a metro railway line investment in developing countries can have a higher impact on housing sale prices than its impact in the post-construction (operational) stage. In the case of İstanbul, the related speculation effect of a metro railway line project (in its announcement stage) on housing sale prices is almost twofold when compared to the post-construction impact. The results of the OLS models indicate that with the announcement of a metro railway line project, every 100 m reduction in the distance of the housing units to the planned metro railway line station brings an increase of 9,098 TL in the price of the housing units, whereas this increase is only 4,344 TL per 100 m in the post-construction phase. In the case of the Esenler/Kirazli and Atakoy/Ikitelli metro railway lines in İstanbul, the results of the average treatment effects model indicate that with the announcement of the project, the average price increase of a housing unit is 86,756.37 TL more than the average price increase in the post-construction phase. Indeed, the increases in housing prices before construction of the metro railway line project decline almost twofold after construction in the long-run. Thus, following construction of the metro railway line projects, almost half of the housing price increases before construction of the project would have been capitalised on by the metro railway line investment for itself in the long-run.

There are numerous studies that report the different response of housing units in developed and developing countries. For instance, in developed countries, the housing market is affected negatively in locations very near to the station; this is associated with the nuisance effects of stations such as noise, vibration, visual pollution, and/or discomfort during the construction period, as is the case in American cities like Houston, Phoenix, Virginia, and Queensland, Sydney in Australia (Pan, 2013; Seo et al., 2014; Wagner et al, 2017; Yen et al., 2018; Mulley et al., 2018). By contrast, studies in developing countries experience value uplift even in the very near locations (Zhang and Wang, 2013), such as in Beijing in China, which was verified by our findings.

Determining the potential reasons for these findings will be a productive avenue for future research. One reason could be reduced accessibility for the households following construction of metro railway line projects due to congestion effects in the long-run. This is because such as decrease in accessibility is not made explicit within the declaration stage of the projects. Another reason could be the capitalisation effect of the related metro railway line project in the long-run, which is different from the short-run. In other words, urban railway investments capitalise the surrounding land and housing values in the short-run while in the long-run equilibrium, it begins to capitalise itself, resulting in shifts in related value increases from the land and houses to the urban railway facilities. Thirdly, it could have been caused by changes in the preferences of related social groups in consuming land/housing and commuting cost under their budget constraints, as revealed by Forouhar and Hasankhani (2018). Further comprehensive studies and measurements are needed to verify such speculations, especially for cities in developing countries with also adding the average income or the salaries of the families participating in the related future surveys in order to improve this study.

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