Abstract

With the rapid construction of metro line systems in the cities of China, the impact of introduction of metro lines on housing prices has become a major concern. Majority of cities in China are introducing metro line systems to ease urban problems such as traffic congestion and environmental pollution while providing their urban residents with accessibility, fast travel times and low travel costs. Also, the rapid construction of metro lines is associated with increased infrastructure investment from the Chinese government post the global financial crisis and the increased desire for economic growth among local governments. As the demand for housing near metro stations in the cities of China increases, it is worth exploring the impacts of metro lines on housing prices. Therefore, this paper attempts to investigate whether the introduction of metro line systems has an impact on housing prices. The results are expected to provide information and insights on the extent to which metro lines impact property value which is necessary for financing decisions relating to metro development and transport infrastructure. This paper uses the Difference-in-Difference approach on housing index prices from 60 large and medium-sized cities in China to establish the relationship between introduction of metro lines and housing prices. The results indicate that between January 2009 – January 2016, the introduction of metro line systems in the cities of China positively impacted the housing prices for both newly-built and second-hand housing. However, it greatly impacted the housing prices for newly-built property as compared to second-hand housing, and the impact on houses with 90-144 square meters of floor areas was larger than houses with above 144 square meters of areas. The study also finds that GDP, customer price index (CPI), income and the number of hospitals in the areas positively impact the residential housing prices.

Key words: metro lines, metro stations, difference-in-difference, housing prices, newly-built, second-handed, property value

Introduction

Over the years, cities in China have witnessed rapid urbanization developments from the rapid increase in population and migration of people from rural to urban areas. This has led to an increase in infrastructure construction with a majority of the cities introducing and constructing metro systems to ease problems such as traffic congestion, energy crisis and environmental pollution. As compared to other countries globally, China has been undertaking large-scale metro construction with high-levels of construction speed, investment and scale. As of 2015, 111 metro line systems and 384 transfer stations had been constructed in 25 Chinese cities with a total length of 3295 km (Ding and Xu, 2017). The National Planning Committee in China hoped that by 2020 the metro line system would have reached a length of over 6600 km and by 2050 over 300 new metro lines will have been constructed. With increased infrastructure construction and development, the real estate industry in China has continued to flourish thereby promoting national economic development through higher revenues from properties. As a result, the introduction of metro line systems has been linked to the rise in housing prices in the Chinese cities.

In 2008, only 10 metro line systems were operational in china and majority of them were in the megacities. By 2010, medium-sized cities such as Chengdu, Shenyang and Foshan had their metro line systems in operation with other cities such as Xian, Hangzhou, Zhengzhou, Haerbin and Wuxi introducing theirs in the following years. As of 2015, the number of Chinese cities with metro line systems had rapidly increased as more cities chose to construct the metro. However, the megacities of Shanghai, Shenzhen, Nanjing, Beijing and Guangzhou still ranked the highest among other Chinese cities for the longest service distance and operational time of the metro line systems (Lu et al., 2016).

The rapid development and introduction of metro line systems in the cities of China can be attributed to a number of factors. First, in 2008, the Chinese central government introduced a stimulus package worth four trillion (CNY) to help the domestic economy recover from the global financial crisis (Zhou, Zhai and Shi, 2018). Majority of the

funds in the stimulus package were invested into infrastructure development to cater for the construction of urban metro line systems. The Chinese cities interested in constructing the metro line systems would receive yearly investments for the urban metro projects. As a result, majority of the metro line systems in operation in the cities of china are either government-funded or financed by partnerships between state-owned firms and the local governments. However, for the Chinese cities to receive the yearly investments from the infrastructure stimulus package, they were expected to meet certain requirements implemented by the National Development and Reform Commission (NDRC). These requirements related to factors such as economic power, predicted ridership and population size.

Secondly, the cities of China have embraced the introduction of metro line systems as an urban mobility solution. This is because increased urbanization and rural-urban migration in the country has led to traffic congestion and air pollution in the urban areas. As the metro line systems use underground space it reduces congestion and pollution in the streets (Li, Chen and Zhao, 2017). On the other hand, China has been facing rapid economic growth and an increase in wealth in the past decades, hence the cities can afford the high operational cost of constructing metro systems from the government infrastructure investments.

Thirdly, the cities of China expected positive economic improvements from the introduction of metro line systems. The local governments predicted that the introduction of metro line systems would stimulate an increase in housing prices generating higher revenues to boost economic growth and prosperity with the cities (Zhou, Zhai and Shi, 2018). Furthermore, the revenues generated from increased property values would compensate for the high operational and construction costs incurred. The local governments also believed that the introduction of metro line systems would reduce the travel costs and time for urban residents, thereby increasing the demand for housing near the metro stations. This assured them that their investments would generate higher revenues.

Last but not least, increased competition between the urban cities acted as a driving

force for the rapid construction of metro line systems in the Chinese cities. Majority of the cities of China sought to maximize the benefits of metro development as none of them wanted to be left behind as the others generated higher revenues and experienced rapid growth (Wu, 2017).

Economic fundamentals such as GDP, income levels, and consumer price index (CPI) impact the housing prices in urban areas. The introduction of metro line systems creates job opportunities for the residents that offer better wage, thereby increasing their income levels, as a result the residents become willing to pay higher prices for the houses (Yang et al., 2018). On the other hand, China's GDP is positively correlated to the increase in housing prices, especially for large and medium-sized cities (An, 2014). As a result, GDP relates to the introduction of metro line systems as the construction in China takes place majorly in medium and large-sized cities. In addition, CPI is positively correlated to the increase in housing prices as inflation affects the housing prices.

According to the land capture theory, assessing the relationship between housing prices and metro development helps capture the impact of metro development on housing prices. Evaluating the impact of introducing metro line systems on property prices in Chinese cities is essential for making financing decisions relating to transport infrastructure and metro development (Li, Chen and Zhao, 2019). This is because the metro development projects require huge capital investments and the returns are uncertain. In 2016, cities such a Nanjing, Beijing and Shenzhen experienced huge operating losses as they generated negative returns from the introduction of metro lines (Tang et al., 2021). As a result, it is essential to assess the impacts of metro lines for the Chinese central government, local governments and urban developers to avoid losses in the future.

In recent years, there has been numerous researches on the impact of urban metro line systems on the property value with mixed results being presented in respect to the direction and magnitude of the impact. Most scholars believe that urban metro line systems in urban centers positively impacts housing prices (Hess and Almeida, 2007;

Medda and Modelewska, 2010; Zhang et al., 2016; Gallo, 2018; Wen et al., 2018; Li, Chen and Zhao, 2019; Zhang et al., 2021). This is because the metro line systems provide numerous benefits for the urban residents which contributes to its positive impact on housing prices. The introduction of metro line systems in urban areas improves accessibility for the residents giving them easy and fast access to jobs, medical services, education institutions, entertainment spots and commercial activities (Tan et al., 2019). Improved accessibility increases the demand for housing near the metro station which results in a rise in housing prices. In addition, the introduction of metro line systems has attracted the construction of residential and commercial property near the stations creating employment opportunities with better wages for the residents. The metro line systems also reduce travel costs and travel time for the urban residents which increases the willingness of people to live close to metro stations. Some of the cities in China such as Hong Kong and Tokyo engage directly in real estate developments through rail plus property programs (R+P) that increase the property prices near railways and metros to generate more revenue (Yang et al., 2020).

Majority of the previous empirical studies focus on the impact of metro line systems on residential property prices rather than commercial property prices (ERA, 2006). From the studies, the metro lines positively impact the housing prices for residential property based on the bid-rent theory. In this case, residents outbid each other for houses close to the metro stations which increases the rent and value of these properties. However, some studies suggest that the metro line systems also have negative impacts such as increase crime rate, noise pollution and air pollution near the metro stations (Atuesta et al., 2018; Kang, 2019). These negative impacts affect the housing prices such that the introduction of metro line systems greatly impacts houses in high-income neighbourhoods as compared to lower-income areas due to lower crime rates (Hess and Almeida, 2007).

As a result, the location of the property and distance of property from metro stations places a crucial role in how the metro line systems impact housing prices. This is because the properties near the metro stations experience the highest rise in housing

prices. The impact of metro proximity on housing prices has been a key research topic over the years. The researchers argue that the proximity and accessibility of houses from the metro lines and stations affects their prices (Gu and Zheng, 2008; Wei et al., 2012; Efthymiou and Antoniou, 2013; Wen et al., 2018). Metro proximity increases the accessibility of the residents to employment, recreation activities and retail, hence the advantages are reflected in the value of property (Forouhar, 2016). It is evident that the introduction of metro line systems causes an increase in housing prices for houses within 2km of the metro stations and metro lines, especially in suburban areas.

Other researchers believe that the impact of metro line systems on housing prices differs depending on the construction period. During the early construction stages, the impact on property value is minimal as the government is yet to provide detailed information on the metro system (Cao and Nelson, 2016). In other words, the impact of introduction of metro line systems is also minimal after the announcement of the metro line before construction commences (Keung, 2002). However, as soon as the government announces the financing of the metro line systems, the housing prices increases. It gradually decreases during the construction period up to the opening of the metro line systems (Diao, Leonard and Sing, 2017).

Therefore, it is important to study whether the introduction of metro line systems impacts housing prices. In the next chapter, this paper summarizes empirical research studies related to the development of metro systems in china and relevant literature on the relationship between metro line systems and property prices. The third part provides a description and summary of the data to be used in the study. In the fourth part of this paper, the Difference-in-Difference (DID) method is introduced. For the fifth part, a detailed empirical analysis of the results is provided and a robustness check performed in the sixth part. The last part of the paper provides the conclusion of the research.

Literature Review

Introduction

This chapter presents empirical studies and research on the development of metro systems in China, advantages of metro, impact of metro line system in China and the relation between metro systems and property prices.

Development of the Metro System in China

Over the years, there has been a rapid rise in the development of public transit systems such as the light rail transit (LRT), metro and bus rapid transit (BRT) systems in the cities of China. The BRT system involves the use of buses at metro-level capacities for public transport while providing fast, high-quality, comfortable and reliable transit. In China, the number of BRT systems in the cities of China have tremendously increased mainly in megacities such as Shanghai and Guangzhou and small and medium-size cities with lower populations (Guarda et al., 2017). Salon, Wu and Shewmake (2014) determined that major cities in China such as Guangzhou have both the bus rapid transit lines with the highest capacity and extensive metro rail systems. The metro unlike the BRT system is a form of public transport that carries a high-capacity of individuals and utilizes underground spaces in urban areas for transit. Lin et al. (2021) pointed out that China is currently the leading country in the world in relation to the speed and planning for the construction of metro systems in its cities.

Pucher et al. (2007) argued that rapid transit is mostly associated with rail rather than buses, which challenges the success of the BRT system in China. In addition, Deng, Ma and Wang (2013) revealed that the public holds negative perceptions of the buses due to delays and traffic. Guarda et al. (2017) also pointed out that the BRT systems in Chinese cities ranked significantly lower than in non-Chinese cities due to their designs. These challenges limit the development and popularity of BRT systems in China. As a result, metros have increased popularity and developed quickly in the cities of China.

Zhou, Zhi and Shi (2018) stated that the development and construction of metro

systems in the cities of China gained popularity over the past decade after the 2007/8 financial crisis. This is because the global financial crisis weakened China's domestic economy which pushed the government to increase investments and developments in infrastructure including metro systems.

The rapid and continuous urbanization, and population of the cities of China also influences the development of metro systems. Loo and Li (2006) found that the rapid urbanization in the cities of China contributes to the development of the metro systems because of increased demand for mobility, especially in the large cities such as Shanghai and Guangzhou. The development of urbanization and increased rural-urban migration results in an increase of population in urban cities. As a result, Li, Liu and Lv (2021) also suggested that the development of urbanization and population increase in the cities comes with an increased demand for infrastructure and housing. Loo and Li (2006) point out that population influences the development of metro systems as demand for public transit increases with high population in the cities. The results of Lin et al. (2021) indicated that cities with larger populations in China develop metro systems that are longer, extensive and with more metro stations and lines as compared to low-population cities.

Lu et al. (2016) stated that there has been a rapid and continuous development of metro systems in China over the years, hence studying the impact of metro line system in China is of great importance. This is because it will help provide information and insights on urban transit policy and planning, service improvement and financial investment. On the other hand, Zhao, Cao and Lu (2021) argued that it is important to study and understand the impact of metro line systems as metros are rapidly developing in second-tier cities. Fu and Gu (2018) pointed out that with the rapid development of new metro lines in the cities of China it is important to study the impacts of metro line systems to assess performance. Li et al. (2021) found that in order to attain and maintain sustainable transit-oriented development, it is important to evaluate the impact of metro line systems in China as it depends on passenger satisfaction and experience.

Advantages of Metro

Li, Chen and Zhao (2017) defined the advantages of metro lines in relation to high speed, low carbon emissions and minimal energy consumption as compared to other methods of public transport. El-Geneidy et al. (2016) stated that Metros are beneficial as they improve transport equity by serving the entire population and enable the citizens to reach their specific destinations. Li and Zhao (2017) found that Metros help the cities to achieve transit-oriented, urban and economic developments. The metro line systems are beneficial in easing traffic congestion in cities as they utilize underground space. The metro also reduces pollution, provides cheaper transportation to citizens and carries a large number of people at the same time due to its high-capacity.

Metro Systems and Property Prices

Majority of previous empirical studies focus on the effects of the development of metro on housing prices. Zhou, Zhai and Shi (2018) conducted a qualitative study to determine factors influencing the development of metros in the cities of China. The results showed that intercity competition, strong economy and the expected benefits of the metro pushed the Chinese cities to develop the urban metro systems. Debrezion, Pels and Rietveld (2007) studied the impact of accessibility of railway on housing prices using previous empirical studies. The results of their study indicate that the coverage and network connectivity of railway lines influences property value and commuter rails have the most significant impact on housing prices. Gallo (2018) used a hedonic model to evaluate the impact of transit systems on property prices in Naples. The results show that high-frequency metro line systems increasing housing prices by 20-25%, whereas low-frequency metros and bus lines have no significant impact. Similarly, Sun, Wang and Li (2016) used the hedonic pricing model to analyze changes in property value within 1km of subway lines in China. The results show that the construction and distance of subway lines contribute to an increase in nearby housing prices.

Li, Chen and Zhao (2019) used a spatial error model to evaluate the impact of metro

systems on housing prices in Beijing. The results indicate that areas close to the metro lines have more employment opportunities which results in an increase in housing prices. Furthermore, regions with more than one metro line have higher property values due to high accessibility for the public. On the other hand, Zhang et al. (2016) conducted quantitative analysis using panel data to assess the effect of rail transit facilities and stations on housing prices. The results indicate that urban rail facilities influence a 0.0233% increase in property value for every 1% increase in rail transit. Hess and Almeida (2007) also found that new metro line systems in the USA such as metro rails positively influence property prices as they increase the price of lands by a value between $0.99-$2.31. However, majority of the previous studies fail to fully investigate the specific factors that account for the relationship between metro line systems and property prices.

Metro Proximity

Wen et al. (2018) used the hedonic price model based on the ordinary least squares regression to evaluate the impact of rail transit on property value in Hangzhou, China. The results show that accessibility and proximity to subway station within 2 km increases housing prices by 2.1%-6.1% higher than houses further away from the stations. Furthermore, the impact is higher for property in suburban areas as compared to urban areas in the cities. Similarly, Gu and Zheng (2008) found that metro station proximity mainly influenced property prices for houses in suburban areas. Efthymiou and Antoniou (2013) pointed out that the housing prices for properties near metros tend to be higher as compared to those far from metro systems. Wei et al. (2012) found that the housing prices for properties near Line 1 of the Chengdu metro increased averagely at a rate of 9.51% due to proximity to the metro. Bae, Jun and Park (2010) establish that the distance from the subway station increases the property prices only before the metro lines are opened. Zhang et al. (2021) also found that the distance to the nearest rail station has a positive impact on property value for houses near the rail stations in Stamford and a negative impact for property near bus lines. Ren et al. (2021) found that metro proximity influences housing prices such that

houses between 250-500m of the metro stations have prices 7.8% higher than property beyond 1500m. Furthermore, the study reveals that influence of transport accessibility on low-middle and high price housing decreases steadily.

Quality of Metro Systems

Gallo (2018) established that the quality of metro line systems also influences housing prices. Higher quality and higher-capacity metro systems in urban areas boost the activity and accessibility in the areas which increases the land values. Bohman and Nilsson (2016) also suggested a positive correlation between high quality metro systems and property prices.

Accessibility to Services

Medda and Modelewska (2010) determined that the accessibility of public transport influences housing prices as it causes the value of property to increase by approximately 6.7 – 7.2%. This is because the metros provide the public easy access to jobs, education, medical services, entertainment and commercial activities leading to a rise in housing demand, hence land value rises. Taiwan, Lin and Cheng (2016) also pointed out that metros greatly influence housing prices for nearby properties in Taiwan as they improve job accessibility for the public which boosts housing demand resulting in a rise in pricing. Du and Mulley (2006) used the Geographically Weighted Regression (GWR) model to assess the relationship between transport accessibility and property value. The results show that public transport improves access to amenities and jobs for the public which increases land value. In contrast, Adair et al. (2010) argued that accessibility has minimal influence on housing prices at city-level, but increases property prices for low-income regions within the cities.

Development of Urbanization

The metro systems impact property prices through the development of urbanization. The study by Lu and Ou (2014) showed that the rapid development of urbanization increases housing demand as it influences the expectations of people in relation to the process of urbanization leading to a rise in housing prices. Li, Liu and Lv (2021) also

suggested that the development of urbanization and population increase in the cities comes with an increased demand for infrastructure, transit development and housing which increases the housing prices. Wage income is also higher with the continuous development of urbanization in the large and medium cities in China. Xu, Zhang and Aditjandra (2016) suggested that urban rail transit in the city of Wuhan, China impact property value with 16.7% increase in housing prices for property between 0-100 m and 8% for houses between 100-400m from the rail stations.

Population Migration

The metro line systems influence property prices by contributing to population migration as people move into areas near metro lines due to presence of more employment opportunities, job accessibility, low commuter fares and less traffic. Wang and Huang (2005) found that population migration influences GDP growth, especially for the cities in eastern China. As a result, the large cities in Eastern China receive a higher population of immigrants and labour forces which improves economic development in the regions and results in higher housing prices. Lin et al. (2018) studied the effect of population migration on housing prices in the urban regions. The results portrayed that population migration on a national level had significant influence on urban housing prices, whereas migration had minimal impact on a regional level. Garriga et al. (2021) suggested that the relationship between housing prices and population migration greatly depends on economic and policy climate in the different geographical locations. For example; in China, the local supply of land and geographic restrictions influence how population inflows impact housing prices.

Difference-in-Difference Model

Trojanek and Gluszak (2018) integrated the difference-in-difference model together with the OLS, spatial error model, spatial autoregressive model and spatial general model to assess the impact of public transit on housing prices. The difference-in-difference model enables an analysis of the impacts before and after construction of the public transit systems. Chang, Ming and Chuan (2020) stated that the difference-

in-difference model effectively evaluates the impact on housing prices before and after the construction of metro in areas near and far from the public transit systems. The results of the study indicate that the metro line systems have different impacts on housing prices during the two phases of before and after construction. Yazdanifard, Joshaghani and Talebian (2021) used the difference-in-difference model to determine the impact of metro stations on housing prices by using adjacent properties as the treatment group and distant houses as the control group for the study. The results portray that adjacent properties are significantly affected by presence of metro stations in terms of housing prices as compared to distant properties.

Wen et al. (2018) found that using the ordinary least squares (OLS) model to assess the impacts of public transit on housing prices fails to incorporate the different impacts of mass public transit systems on various housing prices. In addition, Ren et al. (2021) states that the OLS regression model is prone to outliers and errors. Using the quantile regression model, Wen et al. (2018) established that the influence of metro on housing prices is higher in high-end property areas as compared to mid regions, whereas Mathur (2020) found a differing outcome that the price premium decreases as the quartile increases. This shows that the regression model provides differing results in relation to the impact of metro on housing prices, hence it is unreliable. On the other hand, Forouhar (2016) used the difference-in-difference model to assess the effects of expanding transit lines on property value as it compares change over a period of time. Furthermore, the model eliminates biases and errors by comparing the treatment and control groups and establishing the differences.

Data:

In this research, I would use the data from the National Bureau of Statistics, CEIC, China Real Estate Information and also public documents from different cities to investigate the effect of introduction of metro line system on property housing prices in various cities.

1. **Metro Line System**

Year	City where the first metro line under operation
2010	Chengdu, Shenyang, Foshan
2011	Xian
2012	Suzhou, Kunming, Hangzhou, Hangzhou
2013	Haerbin, Zhengzhou,
2014	Changsha, Ningbo, Wuxi.

2.House Price Index

Since 2016 the property prices in China had experienced an unsual rise. In order to investigate whether the metro line system has impact on property housing price and the impact on various scale cities, this research would use data from 60 large and medium-sized cities in China between January 2009 to January 2016. This research would use House price index in monthly interval from National Bureau of Statistic as the measurment index of property price changes. The housing price index is the number that represents the overall trend of residential property price in commodity level including second handed property housing price index in 70 large and medium size cities. This

research aims to explore the impact of introduction of metro line systems on property housing prices which is the explained variable in this paper. The property housing price is composed of residential properties of various areas including properties of below 90 square metres, 90-144 square metres, above 144 square metres. Moreover, property housing price also consists of housing prices in various cities including residential housing prices in first-tier cities, second tier cities and third tier cities. The detailed data summarization of housing price index can be seen in table 3. And the Name of the variables in the regression can be seen in table 2.

2. Control Variable

Type of variable	Name of varaible	Definition
Dependent variable	New_price	New houses Housing Price index
Dependent variable	New_90	New houses Housing Price index below 90 square meters
Dependent variable	New_90-144	New houses Housing Price index between 90 - 144 square meters
Dependent variable	New_144	New houses Housing Price index above 144 square meters
Dependent variable	Sec_price	Second hand houses Housing Price index
Dependent variable	Second_90	Second hand houses Housing Price index below 90 square meters
Dependent variable	Second_90-144	Second hand houses Housing Price index between 90 -144 square meters
Dependent variable	Second_144	Second hand houses Housing Price index above 144 square meters

Independent variable	D	Whether the metro line system introduced in the city
Control variable	GDP	Gross Domestic Product
Control variable	Hospital	Number of Hospital
Control variable	Invest	Total fixed asset investment amount in each City
Control variable	CPI	Consumer price index
Control variable	Salary	Average Salary

Table 2: Definition of the variables that would be applied in this paper

Besides the independent variable of introduction of metro line systems in this paper, there also exist other variables that might have impact on residential property housing prices. Hence, in this paper, serveral control variables would be added in to ensure the model remain efficient and consistent.

Population density, GDP: two basic economic indicators.

CPI: consumer price index may reflect inflation level associated with the living cost and could reflect level of purchasing power in each city.

Salary: The average salary in various cities might reflect the willingness of making investment and consuming. With higher level of salary in one city, people who live in there would be more willing to spend higher prices on residential housing prices.

Hospital: Hospital in each city is a basic facility that people would take into consideration when they make decision whether to live in one city. More hospitals in one city would increase people's willingness to live in and therefore increase the demand of residential property and the housing prices.

Fixed asset investment: fixed asset investment amount in each city could to some extent reflect the amount of investment in real estate market in each city.

Methodology

In this part, the researcher would conduct Difference in Difference model in multiple time periods to estimate the impact of introduction of Metro system on housing price (Stepen, 2011). As Votsis and Perrels (2016) stated that the Difference in Difference is a method to assess the influence of a policy or event by making comparison with control group and experimental group. The DiD method could only be applied under the assumption where two groups of properties prices show similar trend so that the only reason contributing to the deviation in the pattern of housing price changes is the introduction of the metro line system. The DiD (reference) approach could be used to study the effect of introduction of metro system by comparing the average change in control group with that of treatment group which ensures unbiased causal estimate of the treatment effect. In this study, cities that have metro systems are identified as treatment group and control groups consist of cities without metro services. Before conducting DID approach, one important assumption must be fulfilled which is the housing prices of the treatment group and those of control group must follow a similar trend before metro services are introduced.

$$Price_{i,t} = \alpha + \delta \text{Metro}_i * after_{i,t} + \beta X_{i,t} + \mu_t + \tau_i + \varepsilon_{i,t}$$

The different years and cities are denoted as subscripts t and i respectively. Price is the explained variable representing as housing price index in city i in period t which includes prices of second handed house, new house, second handed house under 90 square meters, between 90 and 144 square metres, above 144 square metres and new house under 90 square metres, 90-144 square metres, above 144 metres. Metro*after is the treatment variable and also DID estimator which represents the metro line introduced in different cities and various months. Metroi is 1 if metro system in city i is under operation; otherwise it is 0. X is a structual characteristic $_i$ and μ_t represent urban fixed effect and time effect. The error term of the regression is denoted as $\varepsilon_{i,\,t.}$

However, this approach may have potential drawbacks. One important issue to be considered is that there might exist other factors that has potential influence on housing prices. For instance, there could be more bus stops and highway stations under operation that increase the convenience of the whole transportation system, which might lead to biased estimates.

Descriptive statistical analysis

Variable	Obs	Mean	Std. Dev.	Min	Max
second_price	5,292	100.2452	0.6595082	98.7	103.3
D	5,292	0.0623583	0.241828	0	1
population density	5,292	42.03077	26.77554	1.756667	152.6667
LNPGDP	5,039	10.86674	6.2879	-6.33824	29.79112
hospital	5,292	35.85676	87.95144	2.75	568
lnIncome	5,292	7.572843	0.2938094	6.972841	8.2213
lnCPI	5,290	7.275365	2.431655	4.295651	16.72381
lnimp_exp	5,292	13.01191	2.471958	4.304065	16.23337

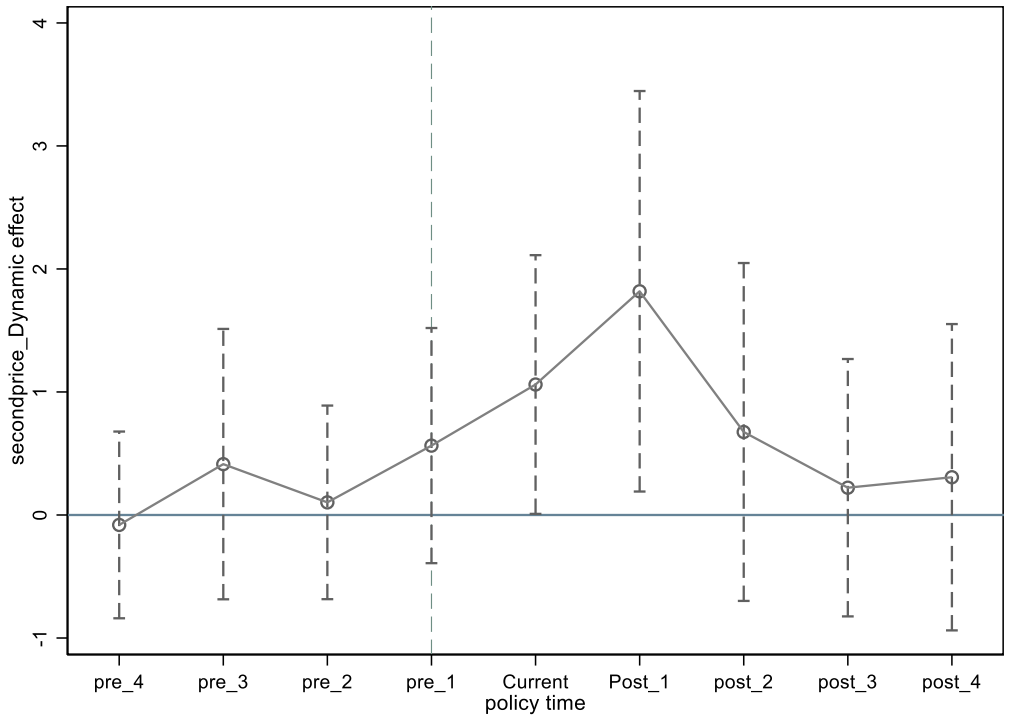
500 words

Empirical results

Parallel Trend Test:

Second_price	Coef.	Std. Err.	t statistic	P>|t|	[95% Conf.Interval]	
pre_4	-0.081	0.379	-0.21	0.832	-0.840	0.678
pre_3	0.414	0.549	0.75	0.454	-0.685	1.513
pre_2	0.103	0.393	0.26	0.795	-0.684	0.890
pre_1	0.564	0.478	1.18	0.242	-0.392	1.520
Current	1.061	0.526	2.02	0.048	0.009	2.112
Post_1	1.818	0.814	2.24	0.029	0.191	3.446
post_2	0.675	0.686	0.98	0.330	-0.699	2.048
post_3	0.222	0.523	0.42	0.673	-0.824	1.268
post_4	0.307	0.622	0.49	0.624	-0.938	1.552
populationdensity	-0.010	0.010	-0.99	0.325	-0.029	0.010
LNPGDP	-0.011	0.002	-4.94	0.000	-0.015	-0.006
hospital	0.001	0.001	2.08	0.042	0.000	0.003
lnIncome	0.047	0.079	0.59	0.555	-0.111	0.205
lnConsume	-0.013	0.012	-1.09	0.282	-0.036	0.011
lnimp_exp	0.178	0.386	0.46	0.647	-0.594	0.949
_cons	98.123	5.026	19.52	0.000	88.066	108.181

Table1: results for parallel trend test on second hand houses



Graph1: results for parallel trend test on second hand houses

Before conducting Difference-in-Difference model, a parallel trend test is required to carry out since assumption of parallel trend would be needed to fulfill. If there is a difference between the time trend of the treatment group and that of the control group, then it means the results using DiD model are not caused by the net effect of implementation of the policy. under the parallel trend condition, the time trend of the control group needs to coincide with the time trend of the treatment group if the control group is not affected by the implementation of the policy. Moreover, the changes of explained variables in the control group have no correlation with the time trend before implementation of the policy and the changes of explained variable are resulting from the policy. Thus, a parallel trend test of residential housing prices between cities with metro line system and cities without metro line system is of necessity to carry out before conducting DID method.

From graph a, if the p value is larger than 0.1, it means the value is not statistically significant and that the result has passed the parallel test. As it indicated in the graph, we could see the p values of second-hand residential housing price pre-1, pre 2, pre 3, pre 4 which is the house price before the implementation of the policy are all larger

than 0.1 meaning the DID method could be applied. From graph (b), before the implementation of the policy, all second handed house price confidence interval of 95% have included 0 which indicates that there does not exist a certain difference between the control group and treatment group. The results implied that DiD model is suitable here. Moreover, the result

Quantitative evidence

Variable	(1)	(2)
	sec_price	new_price
D	0.1141**	
	(2.08)	
population_density	-0.0087**	
	(-2.56)	
LNPGDP	-0.0111***	
	(-6.27)	
hospital	0.0013	
	(1.46)	
lnIncome	0.0191	
	(0.34)	
lnConsume	-0.0116	
	(-1.05)	
lnimp_exp	0.1711	

	(1.47)	
_cons	98.3780***	
	(64.72)	
N	5,038	
R2	0.0140	
F statistic	10.0767***	

Table 3: Results for DID model of new houses and second handed houses

From the table 3 above, we could see impact of the introduction of metro line system on residential housing prices. As the graph shows, the metro line system has significant positive influence on second handed residential housing price. With the introduction of metro line system, the second handed residential housing price has increased 0.1141 points. The population density is negatively correlated with the second handed residential property price, but the result is insignificant. Moreover, the GDP has significant positive correlation with the second handed housing price, which coincide with our expectation. The number of hospitals has significant positive correlation with the second-hand house price index which is reasonable that more basic facilities in one place would increase people's willingness to live in there and thus it would increase the residential housing price. Both income and CPI have statistically significant positive impact on the second handed residential property prices index that is within our expectation. On the one hand, with higher income level in one place, people are more willing to spend higher prices on investing residential properties. On the other hand, CPI is generally used as a measure of inflation and could reflect the price changes associated with cost of living. Investment is positive correlated with the housing price but has a insignificant result.

The results above show that the introduction of metro line system has significant positive impact on both second-hand residential property prices and newly built residential housing prices. But the impact of subway under operation on newly built

houses prices index is more obvious than the impact of that on second handed housing prices index. In this part, we further investigate the impact of introduction of metro line system on housing prices of various floor areas.

Table 4: Results for DID model on second hand houses with various floor areas

Variable	(14)	(21)	(28)
	second_90	Sec_90_144	second_144
D	0.4066**	0.3414**	0.1082**
	(2.34)	(1.57)	(2.32)
population_ density	0.0145	0.0227***	0.0150*
	(1.36)	(4.98)	(1.88)
LNPGDP	-0.0128	-0.0219**	-0.0205
	(-1.21)	(-2.14)	(-1.17)
hospital	0.0055	-0.0016	-0.0020
	(0.86)	(-0.91)	(-1.01)
lnIncome	0.4948**	0.6091***	0.4333**
	(2.57)	(3.73)	(2.51)
lnConsume	-0.1052*	-0.0817	-0.0122
	(-1.75)	(-1.46)	(-0.21)
lnimp_exp	-0.1398	-0.2706	-0.4662*
	(-0.55)	(-1.06)	(-1.95)
_cons	98.2233***	98.8484***	102.5300***
	(31.41)	(31.44)	(30.86)

N	5,038	5,038	5,038
R2	0.0048	0.0042	0.0041
F statistic	8.3333***	14.6447***	7.2035***

t statistics in parentheses

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

In the table 3 above, the introduction of metro line system has positive impact on all the second handed property housing prices of various floor areas. However, the impact is much larger on second handed property houses of floor areas below 90 square metres and 90-144 square metres than the impact on that of above 144 square metres. One possible explanation is that people who could afford houses of larger floor areas could also afford other more expensive options of commuting. The result of residential properties prices above 144 square metres is even smaller than that of the overall analysis above, which further proves our assumption above. With the introduction of metro line system, the second houses prices would increase by 0.4066, 0.3414, 0.1082points of houses with floor areas below 90 square metres, 90-144 square metres and above 144 square metres respectively. The results are statistically significant for houses with floor areas of below 90 square metres, above 144 square metres and not significant for houses with floor areas of 90-144 square metres.

Compared with the overall analysis above that the impact on second handed residential housing price is slightly larger than newly built residential housing price, the gap of those impacts between new houses and second handed houses after dividing into is smaller. Moreover, the prices of houses with floor areas between 90 to 144 square metres are mostly influenced for both newly built residential properties and second handed houses. These results are within expectation since the demand of properties with floor area of 90-144 square metres is the largest. In conclusion, through conducting Difference-in-Difference model, the results show that the introduction of metro line system could have significant positive impact on both second handed residential property prices and new house prices. Since with metro line

under operation, it could provide people with more options of transportation of commuting and lower people's commuting cost. Therefore, it could increase people's willingness to spend higher prices on buying houses.

Robustness Check

Variable	(1)	(2)	(3)
	second_price	second_price	second_price
D1	-0.2545		
	(-0.51)		
D2		0.2683	
		(1.29)	
D3			0.0001
			(1.21)
population_ density	-0.0086	-0.0090	-0.0081
	(-0.89)	(-1.03)	(-1.11)
LNPGDP	-0.0135***	-0.0072***	-0.0063***
	(-5.41)	(-3.75)	(-3.06)
hospital	0.0012	0.0011*	-0.0005
	(1.58)	(1.80)	(-0.86)
lnIncome	0.5457***	-0.4222***	-0.3917***
	(4.54)	(-3.72)	(-4.09)
lnConsume	-0.0086	-0.0234	-0.0160

	(-0.77)	(-1.66)	(-0.92)
lnimp_exp	0.2191	0.1414	-0.0959
	(0.54)	(0.40)	(-0.29)
_cons	93.9172***	102.0571***	104.9108***
	(17.99)	(22.66)	(23.98)
N	5,038	5,038	5,038
R2	0.0214	0.0251	0.0549
F statistic	9.4627***	6.7180***	21.3719***

Table 7: Robustness checks for new houses

In this part, a robustness check is needed to carry out to investigate whether the results obtained above are robust and reliable. A single period of DID model assuming that the time when the metro line system has first introduced is all in the same month period which is different from the time used above would be conducted.

As the graph () shows, the introduction of metro line system has all statistically insignificant impact on the second handed residential property prices and new houses prices.

In conclusion, the introduction of metro line system has statistically significant impact on both new housing and second handed housing prices.

Conclusion

This paper analyzes whether the introduction of metro line systems in the cities of China impacts the housing prices. By using the DID approach on housing price index data of 60 large and medium-sized cities in China from January 2009 to January 2016, this paper establishes that the introduction of metro line systems positively impacts housing prices. From the results, it is evident that the introduction of metro line systems has a significant impact on both new housing and second-handed housing prices. However, it has the largest impact on the newly built house prices index. In relation to floor area, the introduction of metro line systems has the largest impact on newly built and second-handed houses with 90-144 or below 90 square meters of flow areas, and minimal impact on houses with floor areas above 144 square meters. This study assumes that those who can afford houses with areas of 144 square meters and above can afford private commuting options. Therefore, those seeking to save travel costs through the metro line systems prefer houses with 90-144 square meters of floor area resulting in higher demand.

On the other hand, the results of the DID method also indicate that economic factors such as GDP, number of hospitals, income and consumer price index (CPI) are positively correlated to the increase in newly built and second-handed residential housing prices. The presence of medical facilities in areas near the metro lines and higher income levels among the residents increases the people's willingness to live there and spend more money in buying property. However, factors such as investment and population density have an insignificant impact on housing prices.

Generally, the study finds that the introduction of metro line systems plays a significant role in influencing housing prices in Chinese cities. This is because the metro line systems provide additional transportation means for the urban residents at lower travel costs and time which increases the willingness of people to pay higher prices for housing and properties.

References

Wen, H., Gui, Z., Tian, C., Xiao, Y., and Fang, L. (2018). Subway opening, traffic accessibility, and housing prices: A quantile hedonic analysis in Hangzhou, China. *Sustainability, 10,*2254. https://doi.org/10.3390/su10072254

Li, S., Chen, L., and Zhao, P. (2019). The impact of metro services on housing prices: a case study from Beijing. *Transportation, 46*, 1291-1317. https://doi.org/10.1007/s11116-017-9834-7

Hess, D.B., and Almeida, T. M. (2007). Impact of proximity to light rail rapid transit on station-area property values in Buffalo, New York. *Urban Studies, 44*(5-6), 1041-1068. https://doi.org/10.1080/00420980701256005

Zhang, X., Liu, X., Hang, J., Yao, D., and Shi, G. (2016). Do Urban Rail Transit Facilities Affect Housing Prices? Evidence from China. *Sustainability, 8*(4), 380. https://doi.org/10.3390/su8040380

Zhang, B., Li, W., Lownes, N., and Zhang, C. (2021). Estimating Impacts of Proximity to Public Transportation on Residential Property Values: An Empirical Analysis for Hartford and Stamford Areas, Connecticut. *International Journal of Geo-Inf, 10*(2), 44. https://doi.org/10.3390/ijgi10020044

Wei, X., Zhang, W., Wang, C., and Xu, G. (2012). The Impact of Urban Rail Transit on Surrounding Residential Prices- Line 1 of Chengdu Metro as an Example. *Modern Applied Science, 6*(3), 58-64. https://www.ccsenet.org/mas

Medda, F., and Modelewska, M. (2010). Land value capture as a funding source for urban investment: the Warsaw metro system. http://www.hlrn.org/img/documents/ernst_young_Land_Value_capture.pdf

Zhou, S., Zhai, G., and Shi, Y. (2018). What Drives the Rise of Metro Developments in China? Evidence from Nantong. *Sustainability, 10*(2931), 1-20. https;//doi.org/10.3390/su10082931

Gallo, M. (2018). The Impact of Urban Transit Systems on Property Values: A Model and Some Evidences from the City of Naples. *Journal of Advanced Transportation*. https://doi.org/10.1155/2018/1767149

Forouhar, A. (2016). Estimating Impact of metro rail stations on residential property values: evidence from Tehran. *Public Transport, 8*(3). https://doi.org/10.1007/s12469-016-0144-9

Efthymiou, D., and Antoniou, C. (2013). How do transport infrastructure and policies affect house prices and rents? Evidence from Athens, Greece. *Transportation Research Part A: Policy and Practice, 52*, 1-22. https://doi.org/10.1016/j.tra.2013.04.002

Tang, W., Zhang, F., Cui, Q., and Yan, H. (2021). Evaluation of the land value-added benefit brought by urban rail transit: The case of Changsha, China. *The Journal of Transport and Land Use, 14* (1), 563-582. https://dx.doi.org/10.5198/jtlu.2021.1645

Ding, L., and Xu, J. (2017). A review of metro construction in China: Organization, market, cost, safety and schedule. *Frontiers of Engineering Management*. https://doi.org/10.15302/J-FEM-2017015

Lu, K., Han, B., Lu, F., and Wang, Z. (2016). Urban Rail Transit in China: Progress Report and Analysis (2008-2015). *Urban Rail Transit, 2*. 93-105.

https://doiorg/10.1007/s40864-016-0048-7

Li, S., Chen, L., and Zhao, P. (2017). The impact of metro services on housing prices: a case study from Beijing. *Transportation*. https://doi.org/10.1007/s11116-017-9834-7

Wu, F. (2017). Planning centrality, market instruments: Governing Chinese urban transformation under state entrepreneurialism. *Urban Studies, 55*, 1-17. https://doi.org/10.1177/0042098017721828

Yang, L., Wang, B., Zhou, J., and Wang, X. (2018). Walking accessibility and property prices. *Transportation Research Part D: Transport and Environment, 62*, 551-562. https://doi.org/10.1016/j.trd.2018.04.001

Yang, J., Zhu, L., Duan, Y., and Zhou, J. (2020). Developing metro-based accessibility: Three aspects of China's Rail + Property Practice. *Transportation Research Part D: Transport and Environment, 81*(1). https://doi.org/10.1016/j.trd.2020.102288

Diao, M., Leonard, D., and Sing, T. F. (2017). Spatial-difference-in-differences models for impact of new mass rapid transit line on private housing values. *Regional Science and Urban Economics, 67*, 64-77. https://doi.org/10.1016/j.regsciurbeco.2017.08.006

Cao, X., and Nelson, D.P. (2016). Real estate development in anticipation of the green line light rail transit in St. Paul. *Transport Policy, 51*, 24-32. https://doi.org/10.1016/j.tranpol.2016.01.007

Kang, C. D. (2019). Spatial access to metro transit villages and housing prices in Seoul,

Korea. *Journal of Urban Planning and Development, 145*(3). https://doi.org/10.1061(ASCE)UP.1943-544.0000516

Atuesta, L. H., Ibarra-Oilivo, J. E., Lozano-Gracia, N., and Deichman, U. (2018). Access to employment and property values in Mexico. *Regional Science and Urban Economics, 70*, 142-154. https://doi.org/10.1016/j.regsciurbeco.2018.03.005