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The impacts of mass transit on land development in China: The case of Beijing

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ABSTRACT

Land development impacts of mass transit have long been studied in the developed economies. Yet relatively little is known by the outside world about the Chinese experience due to China's rather short history in the development of modern mass transit and land/property market. This paper attempts to fill the gap by presenting evidence from China, with a detailed case study of Beijing. Selecting three newly built suburban transit lines in Beijing, the study examined land development context and estimated hedonic housing price models to measure the proximity premiums associated with these three lines. The empirical evidence in Beijing, one of the first tier mass transit cities in China, shows that investments in mass transit can have significant and positive impacts on land development. Properties with transit proximity enjoy sizable price or value premiums. The study also confirms the international experience: transit impacts on land development are unlikely to occur automatically; they rely greatly on supportive regional and site conditions. Integrated planning and design for mass transit and land development are critical to expand and maximize the return of transit investments.

1. Introduction

Investing in mass transit is a national strategy in China for mobility provision. On March 1, 2005, the central government issued a policy formally to give a top priority to public transit. Since then resources allocated from the government for mass transit development have been increased steadily. By the end of 2010, the construction and operation of metro rail transit (MRT), light-rail transit (LRT) and/or bus-rapid transit (BRT) had taken place in 25 cities. Inter-provincial high-speed rail (or HSR in operational speeds of 200–350 km per hour) are also booming. Large metropolitan regions such as Shanghai, Guangzhou and Wuhan have begun to develop high-speed commuter rail (popularly called Urban Rail with a design speed of up to 200 km per hour) to link the regional core cities with the surrounding small- to medium-sized cities.

Two main reasons led the central and the local governments of China to put emphasis on mass transit. One is the mobility needs. Along with rapid economic growth and substantial urbanization, demand for inter- and intra-city travel in China has increased enormously. While private motorization continues to rise, the governments are aware of that, given the large amount of total population and limited resources in this country, only mass transit could offer a wise as well as sustainable solution to meet the growing mobility demand. The second reason of emphasizing mass transit comes from the intention of the government to play its role in shaping urban expansion. During the three decades of China's economic reform and development since 1980s, urban expansion took place at a large scale and fast pace throughout the country. Concerns have arisen that the new urban expansion is going toward the Chinese version of sprawl (Cervero & Day, 2008; Ding, 2004; Zhang, 2000). The year of 2011 witnessed China turning into an urban country, with its urban population exceeding 50%. Urbanization will continue in the coming two to three decades. In the process, mass transit can and should play a strategic role in providing sustainable mobility and in shaping urban transformation. It is expected that mass transit investments would guide the spatial expansion of the urban area away from car-oriented sprawl and toward the desirable, transit-based nodal plus corridor development.

The question would then be: did China's mass transit investments achieve the intended purposes? Daily experience suggests that most, if not all, mass transit lines in urban China are serving large volumes of passengers, demonstrating the achievement of the mobility-provision purpose. Validating the second purpose however requires empirical research. The main objective of this paper is to report empirical evidence of mass transit impacts on land development in China. The topic has long been studied in the developed economies.

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Yet relatively little is known by the outside world about the Chinese experience due to China's rather short history in the development of modern mass transit and land/property market.

The theoretical framework for this study is built on locational theory in urban economics. The central feature of the theory states that there exists interdependence among location decisions, land rent and spatial structure; Economic agents choose locations that maximize their profits or utilities. Hence "land rent differentials over space can be explained by transportation cost savings" (Richardson, 1978, pp. 15–16). Public transit increases access and reduces transportation cost (relative to the no-transit case *ceteris paribus*). The improved access in turn would invite competitions among the potential land users in the station areas and along the transit routes. Through the competition, the one who is willing and capable to pay the highest land rent would win the right to use the land. In other words, the transit impacts on land development could be revealed from the value of the land near transit. Based on the theoretical framework, the study examines the capitalization of transit access in land or property values in Chinese cities, with a detailed case study in Beijing.

The rest of the paper is organized as follows. The next section provides literature review on public transit development and its impacts in selected Chinese cities; we then describe three mass transit routes which were recently built to connect city center with the suburban areas in Beijing. In the fourth section, housing project data, hedonic model and spatial econometric methods are used to analyze the capitalization of the three transit routes. The findings are also presented in this section. The final section comes with the discussion and conclusions.

2. Land development impacts of mass transit: empirical evidence from selected Chinese cities

The capitalization of transit access in property values has long been investigated by scholars and policy analysts (Cervero & Duncan, 2002; Cervero & Murakami, 2009). A premium in property price induced by transit services measures the rate of capitalization and indicates positive impact of transit investments, which can be used to develop transit-based policies such as value-capture and transit-oriented development strategies (Batt, 2001). The ongoing interest in the topic has generated a sizable body of literature from different places in the world. Two recent papers reviewed more than 150 publications on this topic (Debrezion, Pels, & Rietveld, 2007; RICS, 2002). These publications however were primarily based on the transit systems in the United States or European countries. Some transit-related studies come from Latin America or developed Asian economies. Mass transit development and its land development impacts in China are relatively rarely told in the existing English literatures. This is partly due to the short history of the development of modern mass transit and land/property market in China. Yet, there are some empirical studies in Chinese journals examining the capitalization of public transit routes. In the following, we present a literature review of the empirical studies on transit routes in selected four major cities in China.

Beijing: Among the first tier of Chinese cities investing in modern mass transit, Beijing has received relatively more research attention than others. Wang, Zhu, and Zhang (2004) studied City Rail, i.e., Line #13, a light-rail system serving the northern suburban area of Beijing.

From a sample of 150 new homes built in 2001-04 along the City Rail line, Wang et al. (2004) found that home price decreased 246 Yuan (about US$36.2[2] per sq. m.) for every kilometer increase in distance to the station. The finding, however was based on simple price comparisons of homes which were grouped by the spatial relationships with the ring roads and with the rail stations (i.e., whether the home is in the areas delineated by the 2nd, 3rd, 4th, 5th, and 6th ring road; whether the home is located within the distance buffer of 1 km, 2 km, 3 km, and 4 km from the rail station). Without controlling for the influence from other factors, for example, home and neighborhood characteristics, the difference in average prices provides limited information on the independent effect of City Rail.

A more rigorous study by He and Zheng (2004) used hedonic model to estimate average housing price as a function of the distance to the station, along with other control variables. The distance variable was measured in binary term depending on whether the sample was located in one of the five distance buffers: <0.5 km, 0.5–1.0 km, 1.0–2.0 km, 2.0–3.0 km, and >3 km. They found that capitalization of City Rail access was presented mainly in the <0.5 km buffer. On average, housing price within the 0.5 km buffer was 1000 Yuan (about US$147 per square meter) higher than that outside the buffer. The model performance however is unknown as the authors did not report the details of modeling output in the published article. Zhang, Ma, and Zhu (2007) applied a similar analytical technique as He and Zheng's paper (2004) except that they defined distance buffers in 0.3 km intervals. They concluded that the influence of City Rail on housing price took place in the area of 1 km from the station and the most significant effect was observed in the 0.3 km distance buffer. The magnitude of the price premium was measured at approximately 206 Yuan (US$30.3 per sq.m.), approximately 1/2–2/3 of what He and Zheng reported (2004). Liang, Kong, and Deng (2007) also utilized hedonic price modeling technique to estimate the price premium associated with City Rail. The study differs from previous studies in measuring distance to transit station as a continuous variable. A total of 16 other variables were included to control for the effects from regional access, structural characteristics, and neighborhood amenities. Their results indicated a premium of 0.464 percent or 28 Yuan (US$4.12) per sq.m. for every hundred meters closer to the station. The distance coefficient, however, only showed a marginal level of statistical significance. It is likely due to the limited sample size ($n = 70$) relative to a model of 18 coefficients being estimated.

A few studies have reported the capitalization of other mass transit lines in Beijing. One published work by Gu and Guo (2008) investigated the effects of Batong Line on housing price. They found no significant evidence system wide. In the submarket of Tongzhou District, which is the eastern portion of Batong, they obtained a significant coefficient for the interaction term between Distance to the Station and the indicator variable Tongzhou. Nevertheless, it is unclear from the incomplete model specification whether the observed effect should be attributed to district location or to transit access.

In another paper, Zheng and Kahn (2008) reported their empirical findings in Beijing on the capitalization of local public goods in housing prices. Proximity to Beijing's rail transit stations was among the local public goods considered by the authors. The study utilized a sample of 900 housing projects in year 2004 and 2005 from the Beijing Housing Transaction Registration System. They then estimated hedonic models of average housing prices as functions of distances to MRT or LRT stations and bus terminals. They obtained estimates of price elasticity of distance to MRT, LRT, and major bus stops being −0.16, −0.04, and −0.08, respectively. However, when the effects of access to parks, schools, university, and other local public goods were controlled, only the coefficient associated with MRT remained statistically significant.

Shanghai: With a sample of 80 apartment sales along Subway Line 1, Chu and Zhou (2004) estimated a linear hedonic price model and obtained a station proximity premium of 25.6 Yuan (US$3.76) per square meter for every hundred meters closer to the station. A

[2] The median exchange rate is 1 US dollar equals to 6.8 Yuan in year 2008, when the data were collected. The exchange rate was provided by the Bank of China, available at: http://www.bankofchina.com/sourcedb/lswhpj/.

recent publication by Pan and Zhang (2008, in English) reported a much larger premium than that by Chu and Zhou (2004). They found that unit price increased by 158 Yuan (approximately US$23.24) for every hundred meters closer to the metro station.

Pan and Zhang's study of Shanghai case is more comprehensive than most published works in that they looked at all three aspects of land use/land development as they relate to Shanghai's rail transit: land use composition, land development intensity, and property values. To identify land use/land development effects, they first created two buffer zones around each of the rail stations. One is the inner buffer with a distance of 200 m from the station. The other is the donut-shape buffer between 200 and 500 m from the station. For each of the buffer zones land use information is assembled and reported in seven land use categories. They are residential, office use, commercial, other public facilities, industrial/warehouse, green space, and transportation. Next, they compared shares of each type of land use between the two buffers. Floor Area Ratio (FAR) was used to measure land development intensity, which is calculated as the ratio of gross building area to gross lot size. They reported that the inner buffer contained a smaller share of residential use than the outer buffer. The study of the between-buffer differences indicated a nodal concentration of commercial (re)development around rail transit stations. Furthermore, the inner buffer was developed more intensively than the outer buffer around metro stations. Land use substitution effect associated with rail transit development was observed.

Guangzhou: Tian (2006, in English) studied the influence of rail transit on residential properties in Guangzhou. From multiple sources she collected a sample of 397 dwelling units along Metro Line 2. With this sample she first conducted a repeat-sales analysis of those units sold multiple times from 2001 to 2004. She concluded that Metro Line 2, which started operating in 2003, had a positive impact on property values. Next, she estimated a hedonic price model showing that for every minute decrease in walking time to Guangzhou's metro station, price increased by 5449 Yuan (US$801) per housing unit. Assuming an average walking speed of 4.8 km (or 3 miles) per hour and an average size of 100 square meters per housing unit, the metro proximity premium is approximately 68 Yuan (or US$10 at an exchange rate of 6.8) per square meter for every hundred meters closer to the station.

Shenzhen: Shenzhen's metro rail system has been in service since 2004. Zheng and Liu (2003) in their study found substantial influence of the system on the local housing market. Specifically, the average housing price within a 400-m distance from the station was 23 percent higher than those in the reference zone of 800–1200-m from the station. In a distance of 600 m, the average price was also 19 percent higher. The results were obtained from a set of hedonic models with a very rich sample of 4993 sales records from 29 real estate projects. In this study, the distance-to-station was coded as dummy variables according to different ranges of distance to the stations. No average prices of the sample were reported by distance buffers. It is therefore impossible to translate their findings of price premiums from percentage to monetary terms.

In summary, existing studies from Chinese cities offered fairly consistent findings in terms of the housing market's positive response to transit access. However, the reported access premiums vary considerably. The variation may be attributed to the regional and local differences in public policies (e.g., car control and transit promotion policies), economic and market conditions, and lifestyle preferences of local residents. Methodological differences among the existing studies also explain in part the varying premium estimates. Rapid transit development in Chinese cities offers ample new opportunities to update the empirical knowledge on mass transit's impacts on land development. The next part presents a focused study of Beijing's housing market as it would respond to mass transit development in the city as well.

3. Land development impacts of mass transit: case study of Beijing

The municipality of Beijing consists of 16 city districts and two rural counties, with a total land area of 16,800 squre kilometers (sqkm). It had a total population of 17.6 million in 2010. Nearly half of the Beijing residents live in the city proper of 735 sqkm. This gives an average population density of approximately 12,000 persons per sqkm in the central area.

In Beijing, the first rapid rail transit was built in year 1969. The initial purpose of this urban rail was not for public transportation services, but rather to provide military support. Connecting city center with the military base in the western suburb of Beijing, the line was part of Beijing's capital defense system to transport army divisions in case of Soviet invasion. After the tension between China and the Soviet Union diminished, the system was transferred to local transit company and began its public services as Metro Line 1 in 1977. Gradual expansion of public transit system took place in the following decade with Metro Line 2 opened in 1987. Mass transit boom did not occur in Beijing until the turn of the century. As of spring 2008 (when the data sets for this study were collected), Beijing has a total of 141 km of rail transit and 16.5 km of BRT systems in operation. Additional seven rail lines and three BRT lines have been constructed for the 2008 Summer Olympics. By the end of 2010, Beijing's rail transit network had a total track length of about 200 km. In its mid-/long-range plans, rail network in Beijing will be expanded to 481 km by 2015 (Fig. 1).

3.1. Characteristics of the three selected transit lines

The study selects three newly built lines that link the central city with suburban communities. Such a sample selection was made considering that suburban locations with vacant land would offer opportunities to better observe land development impacts, if any, of the transit investments. Two of the three lines, City Rail (Line 13) and Batong, adopt the light rail technology. Southern Axis BRT has similar guideway design and vehicle technology to those in Bogota, Columbia.

City Rail serves the northern suburbs of Haidian and Chaoyang districts of Beijing. The alignment takes an inverted "U" shape, with its two ends connecting two major multi-modal transportation nodes in Beijing: Xizhimen and Dongzhimen where passengers can transfer between City Rail and Metro Line 2 (i.e., the Loop Line). City Rail is the first light rail transit line in Beijing. Phase one construction of the line started from the western section in 1999 and completed in 2002. One year after Phase two, the eastern section was opened. The line runs on a service route of 40.85 km with 16 stations. About 64 percent of City Rail's guideway structure (tracks and stations) is on the ground while the rest is elevated or under the ground (Fig. 2).

The Batong line extends metro Line 1 to eastern Beijing. It traverses ChaoYang District where Beijing's central business district (CBD) is being developed, and TongZhou District in the eastern suburb of Beijing. The line is 18.95 km long with 13 stations, two of which share stations with Line 1. Much of the line is on elevated structure, with the route aligned mostly adjacent to or in the median of Jingtong Expressway (Fig. 3). Initial planning for Batong line started in 1993. However, due to several rounds of modification to the plan, construction did not start until 2001. The line began its commercial services at the end of 2003.

The Southern Axis Line is the first BRT line in Beijing (Fig. 4). The line starts from the Qianmen area, the south end of the Tian An Men

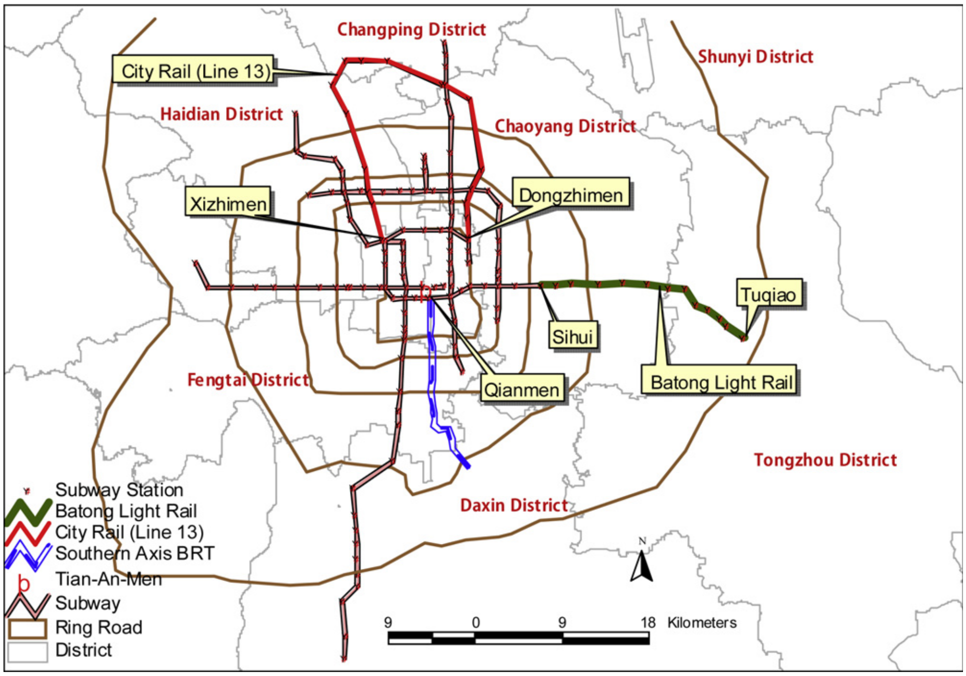

Fig. 1. Mass transit network in Beijing by 2008 and study Area (Source: created by authors, 2008 data).

Square and one of the three major commercial centers in Beijing. It goes out of the Outer Old City of Beijing through the Yongding Gate and ends at the southern terminus of Demaozhuang in the suburban Daxin County. Feasibility study of the BRT line began and finished in year 2003. Right after the completion of the study, the municipal government implemented the system plan in two phases. The initial operation started in late 2004 on a 5-km segment from Qianmen to Muxuyuan station. On December 30, 2005, the BRT line began its full operation with a total length of 16.5-km and 19 stations. Due to narrow streets in the Old City of Beijing, only 13-km of the 16.5-km has exclusive busways. The northern portion of 3.5-km has to share the right-of-way (ROW) with other street traffic. Furthermore, signal priority is not guaranteed at all intersections along the route. All these limitations make the Southern Axis line a bit short from full-scale BRT operations (BCBCL, 2006).

Table 1 below reports system capacity and performance characteristics of the three selected mass transit lines in Beijing. It shows that in 2006 City Rail outperformed other two systems in terms of average operating speed, average passenger volume per station, and year-end ridership. Notably, the BRT line served a volume (32.94 million) nearly twice as much as that by Batong (16.49 million). The BRT route has the highest passenger density (i.e., number of passengers served per km route distance) among the three transit lines. The impressive service performance of the BRT line is mainly due to its high service frequency at the 1-min headway.

3.2. Development along the transit lines

Along the City Rail route, especially the portion inside Haidian District, there has been steadily strong demand for development. The district is home to Beijing's new high-tech park, which is served by City Rail's Shangdi Station. New high-tech firms, either state-funded or joint-ventures, have been burgeoning in the area. A large number of universities and state research institutes are located in the district as well. Students, faculty, staff, and their families provide a large pool of transit ridership, supporting frequent services of City Rail. High level of services in turn attracts further demand for access to City Rail. The northern branch of City Rail runs east-west and serves the north part of suburban Beijing. This area was mostly farmland before the City Rail was planned and

Fig. 2. Beijing's city rail (line 13): XiZhiMen station (left) and residential development by the northern branch of city rail (right).

Fig. 3. Beijing's Batong rail transit Line: SiHuiDong station (left) and system alignment (right).

constructed in late 1990s. By 2003, over 30 residential projects completed, of which the Huilongguan neighborhood alone houses more than 100,000 residents.

The Southern Axis corridor has approximately 200,000 residents in eight residential areas. They are mostly concentrated in the northern portion of the corridor. The BRT line's northern terminal area, the Qianmen Business District, is one of the three regional commercial centers of Beijing. The north portion of the BRT line serves a large volume of traffic generated by the business and population. In contrast, the southern portion of the corridor remains to be less developed. Our field study revealed that the BRT alignment and station siting have limited the system's integration with the development of the surrounding area. The Southern Axis line runs in the central lanes of arterial roads, the traffic on non-BRT lanes in both directions created access barriers to the system (and to the adjacent land uses from the station). Passengers have to climb up and then walk down the skyway from either side of the street in order to use the system (Fig. 4). This inconvenience decreases the attractiveness of the BRT services and likely reduces home buyers' willingness to pay for being closer to the station.

For the Batong Line, an initial investment objective was to promote development in the District of Tongzhou, the eastern suburb of Beijing (In 2005; per capita GDP in Tongzhou was US$2,044, ranking the 15th among 18 districts/counties in municipal Beijing, [Beijing Bureau of Statistics, 2010]). After entering Tongzhou District, the line turns southeast. However, new development did not occur as expected. Consequently, ridership on the Batong Line suffered. Field observations suggest that the system alignment locating in the median of Jingtong expressway is partly responsible while the district's relative weak economy also plays a role. There have been no published empirical studies to verify the observations though.

Table 1
System characteristics of three selected mass transit lines in Beijing.

	City rail (line 13)	Batong line	South Axis line
Technology	Light Rail	Light Rail	BRT
Year Construction Started	1999	2001	2004
Year Initial Service Began	2002	2003	2004
Year Full Service Began	2003	2004	2005
Length (km)	40.85	18.95	16.5
Number of Stations	16	13	19
Max. Transit Unit Capacity (Places)	1200	940	180
Line Capacity (Passengers Per Hour Per Lane; 1000's)	11.28	10.8	10.5
Design Speed (km/h)	80	80	30
Average Operating Speed (km/h)	45	34	25
Peak Hour Headway (min)	4	10	1
Single Lane Width (Meter)	3.5	3.5	3.75
Daily Boardings (1000's)	120	50	90
Year 2006 Total Volume (Million)	42.62	16.49	32.94
Year 2006 Total Volume per km Route Distance (1000's)	1043.3	870.2	1996.4

Source: Compiled from Zhao (2002), BTC (2004), Li (2006), Guo and Wang (2007), and Ye (2007).

3.3. Capitalization of transit access: study methods and data sources

This study applies hedonic price (HP) modeling technique developed by Rosen (1974) for market analysis of heterogeneous goods. HP method has been widely used to measure transit effects on housing price while the price influence of structural and contextual factors (for example, neighborhood characteristics and regional location) are controlled. The basic HP model is shown in Equation (1).

$$p_i = \alpha_0 + \sum_{k=1}^{m} \alpha_k \chi_{ki} + \beta d_i + \varepsilon_i \tag{1}$$

Where: p_i: Average price of the ith residential unit, Yuan/m^2, χ_{ki}: The kth attribute of the ith residential unit, d_i: Distance to the nearest metro station in meters (m), ε_i: random error term, $\alpha_0,\ \alpha_k,\ \beta$: coefficients to be estimated.

HP models may take different functional forms, for example, the linear, the log–log, and the semi-log form. Theory does not prescribe one specific form over the other. For a specific sample, HP model specification is determined empirically based on the assumed relationship between the dependent and the independent variable. In the linear form, the explanatory variable, for instance, distance to the station, is assumed to affect the dependent variable, i.e., housing price in this study, in a constant term. In the log–log form, variables are measured in logarithmic values. The log–log model specification assumes a constant elasticity of housing price with respect to distance to transit station. In a semi-logarithmic model only the dependent variable takes logarithmic transformation. In this model form the effect of one unit change in distance to transit station is measured in percentage terms. These models can be estimated with Ordinary Least Squares (OLS) method.

Housing markets are generally local and diverse. Factors contributing to housing price may exhibit spatial correlations. For instance, the marginal attribute of the same housing feature (e.g., the number of bathroom) to housing price may vary depending on its location in the metropolitan housing market. In another circumstance, the price of a housing unit may be similar to that of another due to their spatial proximity. Presence of spatial correlation may violate the basic assumptions for applying OLS (Anselin,

Fig. 4. Beijing's BRT System: Northern terminus (left photo) and a Typical station (right).

1993; Basu & Thibodeau, 1998). In this study, we propose to use spatial lag and spatial error models to explicitly handle spatial autocorrelation of geographically referenced data, as shown in Equations (2) and (3).

$$p_i = \alpha_0 + \rho W p_i + \sum_{k=1}^{m} \alpha_k \chi_{ki} + \beta d_i + \varepsilon_i \tag{2}$$

$$p_i = \alpha_0 + \sum_{k=1}^{m} \alpha_k \chi_{ki} + \beta d_i + \varepsilon_i \tag{3}$$

$$\varepsilon_i = \lambda W \varepsilon_i + \mu$$

Where: ρ, λ: spatial autoregressive (i.e., Rho and Lamda) coefficients, W: Spatial weight matrix, μ: random error term.

The data sample used for this study was drawn from three online sources. They are Beijing Real Estate Exchange Information Center (www.bjfdc.gov.cn), Home Search Net (or *Sou Fang Wang* in Chinese, www.soufun.com), and New Wave News (www.sina.com). The first one is a public site maintained by the Beijing Construction Commission. It is one of the most reliable and authoritative sources for Beijing housing market. Home Search Net, a commercial real estate website, lists sales and rental housing information for all major cities in China. New Wave News, a major online news media agency in China, provides housing information in its real estate section.

It should be noted that the above sources report the asking prices of new housing units, not necessarily the same as actual sales or transaction prices. Majority of published studies in the Western context use housing sales prices as they better reflect market valuation of housing than asking prices (Debrezion et al., 2007). This study uses asking prices for two reasons, aside from lack of access to housing transaction data. First, the hot housing market in Beijing has given the home buyer little bargaining power. In most cases they have no choice but accepting the published prices. This is indicated by the fact that many home buyers have to wait for months or even a few years after making down-payments before they can see project completion. Second, anecdotal evidence suggests that buyers make under-the-table deals with sellers to report prices lower than actual sales prices for the purpose of reducing price-based transaction fees.

The initial sample data collected from the three sources contains 349, 300, and 194 observations for City Rail, the Batong Line, and the BRT, respectively. Not all of the observations can be used for this study though. Aside from checking consistency of data reporting, we considered two main factors. The first is the spatial extent to which housing samples are located around the stations or stops of the three transit systems. It is expected that transit effects on property development occur in the vicinity of the transit. However, there is no generally agreed threshold to delineate the boundary of "vicinity" around transit stations. Some studies set a threshold distance to transit station or system route and selected only the data points falling within the threshold distance. The distance used as threshold criteria varies, for example, at 0.7-km in Chen, Rufolo, and Dueker (1997), 1-km in Bae, Jun, and Park (2003), 1.2-km in Zheng and Liu (2003), 1.5-km in Rodriguez and Targa (2004), and 2-km in Cheng, Lin, and Liu (2005). One may justify these distance thresholds as they can be used to represent average or acceptable waking distances to the station. It should be noted that model interpretations should vary accordingly when different distance thresholds are used for empirical modeling. The occupancy of fairly large proportion of parking spaces by bicycles in most station areas of Line 13 and Batong suggested that many transit riders combined bike and rail together for travel. An average acceptable distance for biking is certainly longer than for walking. Without having specific knowledge on biking length distribution in Beijing, we use a cut-off distance of 6-km or 30-min. by biking from Batong stations to select the sample points.

Another factor considered in the model specification is time. Previous studies suggest that land market may respond to transit access as early as the announcement of system plan (Knaap, Ding, & Hopkins, 2001). Meanwhile, the accessibility to the transit system might not be fully capitalized until a certain time after the system is in service (Chen et al., 1997; Weinstein & Clower, 2002). This study tries to capture both the speculation and the time lag effect. Hence we include data records starting from the year when the system construction was formally announced and ending at the year after the system had been in full service for two or more years. With these considerations, we selected the data records from 1999 to 2005 for City Rail, from 2001 to 2005 for the Batong Line, and from 2003 to 2007 for South Axis BRT.

The study models average housing price, i.e., the dependent variable, as a function of four sets of explanatory variables (listed in Table 2). The first set of explanatory variables is used to describe structural characteristics of the housing projects. Variables describing physical characteristics include dwelling type, degree of finishing condition, green area ratio, and floor-area ratio (FAR). A limitation of the online data sources is that the housing data are project-based (a project is analogous to a subdivision in the U.S.). If one project has different types of dwelling units, for example, studio, 2–5 bedrooms, and villas, we were not able to obtain detailed information for specific attributes of each type of housing units. Only project-level information such as the average asking price (Yuan per square meter), the green space ratio, and the FAR is made public.

Table 2
Sample descriptive statistics.

Variable	City rail				Batong				BRT			
	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max
Price (Yuan/Square meters)	5914	2203	2650	20000	5544	2973	1700	21000	8569	6784	2800	50000
Distance to Transit Station (network distance in meter, 100 s)	14.36	9.80	1.1	41.6	16.76	12.58	0.3	59	14.58	7.86	0.5	29.92
Distance to the City Center (airline distance in kilometer)	16.64	6.64	7.01	30.72	17.92	7.12	5.80	31.94	6.91	3.45	0.50	17.79
Housing Type (1 for villa or high-end units; 0 for apartments or regular units)	0.34	0.48	0	1	0.11	0.31	0	1	0.34	0.48	0	1
Home Finishing (1 for fine finishing; 0 for others)	0.23	0.42	0	1	0.20	0.40	0	1	0.37	0.49	0	1
Green Area Ratio in the Project (%)	35.82	6.38	20	62	37.20	8.00	10	70	32.54	8.01	0	50
FAR (Floor-Area Ratio) of the Project	4.13	3.67	1.05	21.42	2.54	1.63	0.15	12.5	3.04	2.07	0.81	13
Access to Expressway (For City Rail: 1 if in 2 km; 0 otherwise; Others in km)	0.80	0.40	0	1	0.98	1.23	0.02	5.64	0.87	0.57	0	3.57
Access to Health Centers (1 if in 2 km; 0 otherwise)	0.49	0.50	0	1	0.60	0.49	0	1	0.61	0.49	0	1
Access to Public Parks (1 if in 2 km; 0 otherwise)	0.11	0.31	0	1	0.23	0.42	0	1	0.47	0.50	0	1
Access to Sports Facilities (1 if in 2 km; 0 otherwise)	0.09	0.29	0	1	0.21	0.41	0	1	0.72	0.45	0	1
Home Availability (1 for immediately available; 0 for waiting after down payment)	0.84	0.36	0	1	1.41	3.28	0	15				
District 1 (1 if in District 1; 0 otherwise)	0.48	0.50	0	1	0.49	0.50	0	1	0.28	0.45	0	1
District 2 (1 if in District 2; 0 otherwise)	0.03	0.16	0	1	0.51	0.50	0	1	0.09	0.29	0	1
Year 1999 (1 for year 1999; 0 otherwise)	0.06	0.25	0	1	0.01	0.09	0	1				
Year 2000 (1 for year 2000; 0 otherwise)	0.15	0.36	0	1	0.04	0.20	0	1				
Year 2001 (1 for year 2001; 0 otherwise)	0.18	0.38	0	1	0.07	0.25	0	1				
Year 2002 (1 for year 2002; 0 otherwise)	0.24	0.42	0	1	0.04	0.19	0	1				
Year 2003 (1 for year 2003; 0 otherwise)	0.15	0.36	0	1	0.08	0.27	0	1	0.32	0.47	0	1
Year 2004 (1 for year 2004; 0 otherwise)	0.13	0.34	0	1	0.12	0.33	0	1	0.33	0.47	0	1
Year 2005 (1 for year 2005; 0 otherwise)	0.09	0.28	0	1	0.30	0.46	0	1	0.19	0.39	0	1
Year 2006 (1 for year 2006; 0 otherwise)					0.34	0.48	0	1	0.05	0.22	0	1
Year 2007 (1 for year 2007; 0 otherwise)									0.11	0.31	0	1
No. of Observations	217				275				100			

Note: City Rail Model: District 1 for Haidian, District 2 for Xicheng; Batong Line Model: District 1 for Tongzhou, District 2 for Chaoyang; BRT Model: District 1 for Xuanwu; District 2 for Daxing.

The second set of variables includes site and district locations. Distance to Transit Station is the main interest of this study. Regional factors, for example, regional location relative to city center and sub-centers and district income and educational quality et al. all matter to home prices. A growing number of scholars have been investigating the transforming spatial structure of Beijing in the increasing presence of market forces. Han (2004) studied Beijing's spatial structure and concluded that "Beijing's residential property value surface looks like a castellated rooftop", illustrating Beijing neither a monocentric nor a polycentric city (Han, 2004, p. 1259). Another study by Zhou and Ma (2000) showed that suburbanization in Beijing was "still at the incipient stage of development with suburbs dominated by central city" (Zhou & Ma, 2000, p. 205). To control for the effects of Beijing's spatial structure on prices, this study includes Distance to the City Center and indicator variables for Beijing's districts as explanatory variables in the housing price model. The third set of variables characterizes local access to public services or amenities such as expressways, health centers, public parks, and sports facilities.

Finally, the fourth set of variables includes time indicators. Since the sample data was pooled from different years, a set of dummy variables is included in the model to indicate the years when the housing unit entered the market. They account for the effects of macro factors, for instance, inflation, economic cycles, and housing reform policies, which all would affect the housing sales prices. In addition to years, a variable Home Availability is also included to capturing the potential price effect of waiting for home completion after the buyer has made initial payments.

The home prices were listed prices for new housing projects at the time when the projects went to the market for the first time. In the case that the housing project has more than two marketing phases, there would be multiple home records taken for the same project. These records share the same neighborhood features, locational attributes, and even structural characteristics. The only difference was the different timing when the housing units went to the market. It is thus statistically problematic to include multiple records from the same project when no additional structural variables are available to distinguish among different units of the same project. For final modeling, only one record from the same project for the same year of the listed price was included.

With all these considerations and after deleting the records with missing values on critical variables, the final sample for our analysis contains 217, 275, and 100 valid observations for City Rail, the Batong Line, and the BRT, respectively.

3.4. Results and findings

We first applied OLS regression to estimate the hedonic price models for the three transit lines, testing various model specifications as shown in Equations (1)–(3). With the initial OLS modeling outcome, we conducted diagnostic tests for spatial autocorrelation. The results suggest the presence of spatial error dependence in the City Rail sample and substantive spatial dependence in the Batong sample. No spatial autocorrelation was detected with the BRT line.

Accordingly, we estimated spatial models for City Rail and Batong. Table 3 reports the final modeling results. For reference, we also estimated spatial models for the BRT line although the initial tests did not suggest spatial autocorrelation in the BRT sample. The statistically insignificant lambda coefficient for City Rail model suggests that the spatial error dependence detected in the initial test is negligible. The insignificant *rho* coefficient in the spatial lag model of BRT reconfirmed that there was no observed spatial autocorrelation with this sample. Spatial autocorrelation then has

Table 3
Spatial hedonic housing price modeling: WLS results.

	City rail (spatial error)			Batong line (spatial lag)			BRT (spatial lag)		
	Coef.	Std. Err.	t-stat.	Coef.	Std. Err	t-stat.	Coef.	Std. Err	t-stat.
Distance to Transit Station	−0.0035	0.0012	−2.89**	−0.0213	0.0230	−0.93	−0.0017	0.0044	−0.38
Distance to the City Center	−0.0419	0.0036	−11.76**	−0.6034	0.0704	−8.57**	−0.0943	0.0165	−5.70**
Housing Type	0.1001	0.0282	3.55**	0.3851	0.0572	6.73**	0.4106	0.0702	5.85**
Home Finishing	0.1805	0.0297	6.07**	0.1680	0.0450	3.74**	−0.0050	0.0742	−0.07
Green Area Ratio	0.0029	0.0019	1.49	0.0028	0.0022	1.28	0.0111	0.0037	2.98**
FAR (Floor Area Ratio)	−0.0008	0.0031	−0.25	0.0053	0.0109	0.49	−0.0131	0.0152	−0.86
Access to Expressway	−0.0190	0.0318	−0.6	0.0575	0.0126	4.56**	0.0001	0.0001	1.07
Access to Health Centers	0.0713	0.0353	2.02**	−0.1269	0.0465	−2.73**	0.1536	0.0870	1.77*
Access to Public Parks	0.1063	0.0373	2.85**	0.0401	0.0433	0.93	−0.0527	0.0737	−0.72
Access to Sports Facilities	0.0887	0.0419	2.12**	0.0327	0.0427	0.77	−0.0605	0.1003	−0.60
Home Availability	0.1092	0.0334	3.27**	0.0006	0.0054	0.10			
District 1	0.2784	0.0356	7.81**	−0.0753	0.0555	−1.36	0.1986	0.1035	1.92*
District 2	0.2785	0.0730	3.81**				0.3352	0.1467	2.28**
Year 2000	0.0464	0.0499	0.93	−0.2749	0.2023	−1.36			
Year 2001	0.0849	0.0492	1.72*	−0.1032	0.1994	−0.52			
Year 2002	0.1336	0.0474	2.82**	−0.1428	0.2038	−0.70			
Year 2003	0.1876	0.0508	3.7**	0.1099	0.1944	0.57			
Year 2004	0.2206	0.0515	4.28**	0.1434	0.1929	0.74	0.1107	0.0720	1.54
Year 2005	0.2886	0.0560	5.15**	0.2395	0.1899	1.26	0.4147	0.0871	4.76**
Year 2006				0.4200	0.1896	2.22**	0.3088	0.1426	2.17*
Year 2007							0.6895	0.1043	6.61**
Constant	8.7942	0.1285	68.46**	13.6781	0.7519	18.19**	8.6671	0.2593	33.42**
Lambda/Rho Coefficient	−0.0000	0.0000	−0.30	0.0004	0.0001	2.93**	0.0002	0.0004	0.58
No. of Observations	217			275			100		
Variance Ratio	0.7710			0.6870			0.7610		
Squared Correlation	0.7730			0.6870			0.7610		

See Table 2 for notes (**<5%; *<10%).

caused biased and unreliable OLS estimate of transit access premium for Batong line.

3.4.1. City Rail model

In the City Rail model, the estimated coefficient for Distance to Transit Station has a negative value of −0.0035. It means that, as the housing project is farther away from the station, housing price drops. Transit proximity premium is indicated by the magnitude of the coefficient: for every hundred meters closer to the station, the housing price increases by 0.35 percent, all else being equal. Given the sample average of housing price at 5914 Yuan (US$869.71) per square meter, the percentage change in price is transformed to 20.7 Yuan (approximately US$3) per square meter. It is slightly lower than that reported in an earlier study on City Rail (Liang et al., 2007), which found 0.4 percent change in price for every hundred meter distance variation. Nevertheless, the estimated distance coefficient in that study contained a rather large standard error relative to our results. We found that premium estimate was sensitive to spatial sampling. If we restrict the sample to those located within 2-km of City Rail, the estimated coefficient for Distance to Transit Station became −0.0066, which is translated to 41.1 Yuan per square meter (US$6) for every hundred meters closer to the City Rail station.

As the urban economics theories suggest, homes closer to the city center are sold at higher prices than those in farther locations. Beijing has developed a regional housing and land market, transforming gradually from a planned economy to increasingly market-oriented in last three decades (Ding, 2004). The locational effect from this region-wide indicator was confirmed in the City Rail model: A statistically significant coefficient was identified for the variable Distance to the City Center (i.e., the Tiananmen Square). The estimate indicates that, for every kilometer closer to the city center, housing price increases by 4.19 percent.

Two dummy variables indicating the district location of housing projects display statistical significance at the 99 percent level. The magnitude of the estimated coefficients reveals that home buyers are willing to pay 27.8 percent more in order to live in Haidian District or Xicheng District than in Changping or other suburban districts. Haidian District holds a large number of universities, research institutions, and tourist sites, while Xicheng is a historical district full of attractive neighborhoods and Hu-tongs (allies). In the view of Beijing residents, both Haidian and Xicheng are places with high quality of living. It is thus not surprising to see higher asking prices for homes in those districts than in other areas along City Rail.

The coefficient for Housing Type with an estimated value of 0.1001 suggests that, around the City Rail stations, high-end housing units were priced at 10 percent higher than ordinary housing units. In Beijing (and in other Chinese cities as well), new housing units may go to the market either in a fine-finish condition ready for moving in, or in an unfinished condition for the buyers to customize the interior design and decoration. The price difference between these two types of housing units is nearly 18 percent of average housing price. Access to amenities (e.g., health centers, public parks, and sports facilities) comes with 7–10 percent price premium. Coefficients for green area ratio and FAR have expected signs but they did not display statistical significance. Access to expressways did not translate to a significant price premium either. In China's housing market, not all new housing units are immediately available at the time when buyers make down-payment. In some cases they have to wait for two or even three years before they can move into their new homes. It is thus reasonable to believe that the home immediately available would sell higher than the one available in the future. Our model for City Rail confirms this expectation. The estimated coefficient of "Home Availability" in Table 3 (0.1092) indicates a 10.92 percent difference in housing unit price for these two types of housing units after other variables being controlled.

Note that the coefficients for the year variables become significant after 2002 when City Rail started operating. The modeling result from the City Rail data suggests that, on average, housing price increased by approximately 5 percent annually from 2001 to 2005.

3.4.2. Batong model

The final model for the Batong Line shows rather different results from those for City Rail, despite that the two transit lines share similar technologies (i.e. LRT). The main contrasting result is the coefficient for Distance to Transit Station. Its value of −0.0213 suggests an approximately 0.02 percent price premium associated with Batong access. This is smaller than City Rail in magnitude. Moreover, the premium estimate is insignificant after control for the effects of spatial autocorrelation (Table 3).

A small number of explanatory variables entered the final model with 5 percent or higher level of significance. As expected, Distance to the City Center and Housing Type matter to home price. The price differential between two different home finishing conditions is about 17 percent, similar to that in the City Rail model. A positive coefficient for "Access to Expressway" in Table 3 suggests that a 1 percent increase in distance to the expressway is associated with approximately 0.06 percent increase in housing price. Because much of the Batong line runs in parallel to or in the median of Jingtong Expressway, the nuisance effect of expressway may offset the proximity benefit from Batong Line.

The year coefficients for Batong line model are all insignificant except for the most recent year of 2006. Given that average housing prices in Beijing was increased dramatically, explanation to this seemingly counter intuitive result lies in the local market condition along the Batong corridor. Han (2004) in his study of spatial distribution of residential property values in Beijing shows that there were great variations in housing prices throughout the city. Around the turn of the century, the value of the properties inside of the Third Ring Road was significantly higher than the rest of the city. The land along the Batong Line, which starts from the Fourth Ring Road eastwards and traverses the rural part of Chaoyang District and Tongzhou District, were then less attractive to the potential land users than the land inside of the Third Ring Road.

3.4.3. BRT model

Like Batong model, the results in Table 3 show that there was no measurable influence from the BRT system on housing prices, although the coefficient for Distance to Transit does have the expected negative sign. A quite large premium is found to be associated with regional location. Specifically, every kilometer closer to the city center translates to more than 9 percent increase in average housing price if all else being equal. Increase in green area ratio by 1 percent on the project site yields 1.1 percent increase in housing price. Consistent with the results in the City Rail and Batong models, high-end housing units along the BRT line are sold more than 40 percent higher in unit price than ordinary units. Access to health centers shows marginal level of statistical significance.

The year indicators explain much of the price variation in housing along the BRT line. The estimated coefficient of 0.6895 for 2007 suggests an average annual rate of price increase at over 17 percent from 2003 to 2007. It means that, from 2003 to 07, the market demand at the corridor level along the BRT line had been strong. Therefore the insignificance of the estimated BRT access premium cannot be attributed to regional or corridor conditions. It is thus reasonable to say that unsupportive site factors, e.g., spatial and psychological separation between the BRT line and the nearly neighborhoods, are partially responsible.

4. Discussions and conclusions

According to the existing literatures, evidence reported from selected transit lines in Shanghai, Guangzhou, Shenzhen, and Beijing shows transit's magnetic effect in attracting new or redevelopment to areas where the system goes. Properties with transit proximity enjoy sizable price or value premiums. The detailed analysis of Beijing's three suburban lines in this paper, however, pointed out that transit impacts on land development or capitalization of transit investment are unlikely to occur automatically; they rely greatly on supportive regional and site conditions (Cervero, 2004).

Beijing's two LRT lines, City Rail and Batong, have similar technologies. Nevertheless, only City Rail exhibited significant influences on the price of nearby residential properties, while Batong Line showed no measurable appreciation from the local housing market. One possible explanation to this difference is the design of the two routes. Unlike City Rail, Batong rail line is sharing the ROW with JingTong Expressway and some segments of the routes are located in the middle of the expressway. The route and interchanges of the expressway have occupied some of the prime locations which otherwise could be used for integrated transit-land use development in the immediate vicinity of transit stations. Another possible explanation for the different impacts from the City Rail and Batong Line lies on the relatively weak market demand in eastern Chaoyang and Tongzhou. As of today, Tongzhou remains one of the two least developed city districts in municipal Beijing (which includes 16 city districts and two rural counties) (Beijing Bureau of Statistics, 2010). These unsupportive site, corridor, and regional conditions may contribute to the lack of strong market appreciation for Batong Line.

As for South Axis BRT line, with a service volume of nearly two million passengers per km route distance in 2006, it outperformed the two LRT lines by a significant margin (Table 1). The operational data demonstrates a strong travel demand for public transportation along the South Axis corridor. One would thus expect that the strong travel demand translates into high demand for locations close to the BRT system, which in turn should jack up housing prices in the vicinity of the BRT line. Nevertheless, no considerable capitalization was observed for residential properties proximate to the South Axis. A number of reasons may be speculated to understand the unexpected result. First, similar to the Batong line, the South Axis shares ROW with arterial roadways that form spatial, psychological as well as environmental deterrents (due to traffic pollution) to potential riders from the nearby neighborhoods. Second, the BRT system does not have a permanent fixed guideway, which may present a higher level of uncertainty and investment risk than rail. Third, analytically, the sample size in the BRT modeling may not be large enough to capture the anticipated capitalization effects.

Several limitations still remain in this study, suggesting directions for future research. One limitation lies in the nature of cross-sectional data used for this study. Hence the transit effect on nearby housing may not be interpreted as causal, but more appropriately as indicative. Furthermore, the present study considered residential properties only. The findings therefore should not be generalized to non-residential properties. Studies from other parts of the world indicate that non-residential properties tend to appreciate transit access more than residential properties (Debrezion et al., 2007). Transit effects on retail, office, and other types of properties in Beijing warrant further study. Amid rapid growth of high-speed commuter rail and interprovincial HSR in China, the land development impacts of the new mass transit technologies deserve special attention.

In closing, the empirical evidence reported from selected Chinese cities in general and from Beijing in specific shows that mass transit can have significant and positive impacts on land development. Investments in transit systems could help shape urban spatial outcome in the process of rapid urbanization. The study also confirms the international experience: transit impacts on land development are unlikely to occur automatically; they rely greatly on supportive regional and site conditions. Integrated planning and design for mass transit and land development are critical to expand and maximize the return of transit investments.

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