Negative Externality of Rail Noise and Housing Values: Evidence from the Cessation of Railway Operations in Singapore

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Abstract

The governments of Malaysia and Singapore reached a landmark deal in May 2010 that subsequently led to the cessation of the railway services in Singapore. The nearly 80-year-old railway lines and stations in Singapore, which were leased to and operated by a Malaysian government owned firm, Keretapi Tanah Malaya (KTM), were returned to Singapore's government with effect from July 1, 2011. Residents living in close proximity to the railway lines could enjoy some "quietness" from passing train noise following the termination of the train services. This study uses the cessation of KTM railway services as an exogenous shock in a quasi-experiment design to test real estate capitalization effects of the train noise externalities. Based on the both private and public non-landed housing transactions data in Singapore for the sample period from January 2005 to June 2013, the train noise externality, which was represented by differences in price between houses located within 400 meters from the railway lines (treatment) and those outside the 400 meters boundary (control), were estimated at between 4.7% and 6.6% after the agreement was announced. The capitalization effects of the railway noise externalities on the prices of houses in the affected area increased by 12.1% during the post-implementation periods. The removal of the train noise externalities was translated into a realized economic benefits amounting to S$0.32 billion, based on a sample of houses sold in the post-implementation period.

Keywords: *Noise Externalities, Housing Price, Distance to Railway Line, Keretapi Tanah Melayu (KTM), Treatment, Quasi-Experiment*

JEL Code: D62, H23, R38, R48

1. Introduction

Traffic externalities have long been a politically sensitive issue in many countries. Many governments have been spending millions of public funds on infrastructure projects such as rail transit lines, airports, and major expressways, optimistic that the infrastructure investments could bring positive social, economic, and environmental benefits. Brueckner (2003) finds evidence that airport expansion in Chicago increases service-related job employment. Baum-Snow and Kahn (2000) show that investments in public transit improvements induce people to switch from driving to transit, which consequentially improves local air quality and reduces congestion. Local residents, who were affected by noise and congestion from new infrastructure projects, have actively lobbied and opposed governments' plans to have the projects built in their "backyards".[1] However, the local residents' voice was often muted, and they were also excluded in the planning processes.

Keretapi Tanah Melayu (KTM), a company owned by the Malaysian government, ceased its railway operations on the nearly 80-year-old railway lines connecting Singapore and the Malaya Peninsular in Singapore with effect from 1 July 2011. KTM moved its railway station to the Woodlands Train Checkpoint, near the Singaporean end of the Johor-Singapore Causeway. The railway lands and stations to the south of the new railway station were returned to the Singaporean government. In return, the Singaporean government allocated six parcels of land in the downtown area to M+S Private Limited, a joint venture company set up by the two governments. For residents living along the railway tracks and near the railway stations, the relocation event permanently removed inconveniences caused by the noise of train horns and track alarm system at railway gates, and the vibration of passing trains.

We design a quasi-experiment with the railway cessation event to empirically estimate the discounting (capitalization) effects of railway noise (quietness) on real estate values. We use the distance of housing to rail lines, as a proxy of noise externality, to sort houses that are subject to rail noise into a treatment group, and other houses that

[1] In 1994, a local pressure group bought up a small parcel of land and obstructed the expansion plan for the fifth runway of Schiphol Airport in Amsterdam (Theebe, 2004).

are not affected by such externalities into a control group. Based on the difference-in-differences (diff-in-diff) framework, we empirically estimate the effects of the removal of train noise externalities using housing transactions for the period from January 2005 to June 2013. We found that prices of housing units located within 400 meters from the KTM train lines (treatment group) increased significantly by 4.7% to 6.6% after the announcement of the KTM land-swop agreement in May 2010. The "treatment" effects drove up housing prices by further 12.1% after the implementation of KTM service termination agreement in July 2011. Based on the post-implementation transactions of 2,322 sample houses located within 400 meters from the KTM railway line (the treatment group) with an aggregate value of S$2.97billion as the reference, the realized economic benefits associated with the KTM rail line cessation agreement amounted to approximately S$0.32billion.

We make two contributions to the externality literature. First, our quasi-experiment design overcomes the endogeneity problems that have dogged many past empirical designs. On one hand, airport hubs create service-related employments and bring commercial activities to the surrounding areas (Brueckner, 2003).[2] On the other hand, airports also cause other non-noise related inconveniences, such as traffic congestions in major roads leading to the airports. Similarly, studies on rail externalities also show that high neighborhood crime rate (Bowes and Ihlanfeldt, 2001) and crowdedness in retail activities near rail stations offset the accessibility benefits associated with rail transit nodes. It is difficult to disentangle noise externalities from other correlated effects associated with airports and railway transit nodes. In our quasi-experiment, noise of passing trains that affects residents living on both sides of the railway track is uncorrelated with externalities such as congestion and crowdedness. Accessibility benefit is also not directly relevant to local residents because KTM trains are used mainly for inter-city travelling between Singapore and Malaysia. Therefore, the cessation of railway operations is a "clean" event that represents the removal of noise externality in our *difference-in-differences* (diff-in-diff) strategy; and the event is also "precisely" and unambiguously identified on and after July 1, 2011.

[2] Cohen and Coughlin (2008) show that the distance houses to airport could be negatively correlated with housing prices, if airport noise is controlled. The proximity to airport is an amenity that has a negative price elasticity of -0.15 using housing data near the Atlanta's Hartsfield-Jackson International Airport in 2003.

The test of railway noise externality in a high-rise, high density urban city setting is the second contribution of our study. Train noise transmitting upward in a straight-line pattern affects residents in high-floor units more strongly than those in low-floor units. We found that price discounts attributed to KTM train noise range from 0.3% to 0.8% per floor for houses located within 400 meters from the railway track. The negative externality on residents living in high floor units – say, on the 10^{th} floor – could be translated into a housing price discount of as high as 8% relative to comparable houses on the ground floor.

The remainder of the paper is organized as follows: Section 2 reviews related literature on traffic externalities and housing prices. Section 3 gives the historical background of key events leading to the cessation of KTM railway lines operations. Section 4 describes data sources and descriptive statistics. Section 5 discusses the empirical methodology and identification strategies. Section 6 analyzes empirical findings on how the removal of noise impacts housing prices between the treatments and the control samples. Section 7 concludes the paper with discussions on some policy implications.

2. Literature Review

Many studies have evaluated negative externalities of being in close proximity to transportation nodes, which include airports (O'Byrne, Nelson and Seneca, 1985; McDonald and Osuji, 1995; Tomkins, Topham, Twomey and Ward, 1998; McMillen, 2004; Theebe, 2004; Sobatta, Campbell and Owens, 2007; Cohen and Coughlin, 2008) and rail transit lines (Gatzlaff and Smith, 1993; Bowes and Ihlanfedt, 2001; McMillen and McDonald, 2004). However, McMillen (2004) shows that the expansion of O'Hare Airport in Chicago has, on the contrary, reduced the severe-noise covered area surrounding the airport with quieter aircraft and new flight paths.

In a survey of related literature, Nelson (1980 and 2004) found that housing price elasticity for every decibel reduction in airport noise range between 0.5% and 0.67%. McMillen (2004) estimates that houses that were subject to noise level of above 65 decibels in Chicago's O'Hare Airport area were priced at a discount of 9.2% compared with similar houses that were not exposed to the noise. The noise externality (noise levels above 65 Decibels) was priced at a higher discount of 12% surrounding the Amsterdam's Schipol airport area (Theebe, 2004). Cohen and Coughlin (2008), however, showed that the impact on airport noise caused housing prices to drop by 20.8% if the day-night noise level exceeded 70 decibels. However, they showed that houses located in close proximity to Atlanta's Hartsfield-Jackson International Airport enjoyed positive amenity premiums. Lipscomb (2003) also found that the positive accessibility benefits to Atlanta's Hartsfield International outweigh the negative externality caused by noise generated from the airport.

Weinhold (2013) ran the "*happiness regressions*" using the survey data and showed that noise-induced "*unhappiness*" costs an income-equivalent of €172 per month per household. When examining social costs of noise imposed on different groups of local households, Sobotta, Campbell and Owen (2007) found evidence that discrimination against Hispanics could be used as a predictor of the airport pollution source. Ogneva-Himmelberger and Cooperman (2010) also showed that minority and low-income households near Boston's Logan Airport are more vulnerable to noise externalities.

The studies on rail transit noise externalities showed mixed results. Baum-Snow and Kahn (2000) found positive capitalization of proximity to rail transits into home prices and rents in five US cities: Boston, Atlanta, Chicago, Portland and Washington DC. Gatzlaff and Smith (1993), however, found weak capitalization in the values of residential properties upon the announcement of the Miami Metrorail System. McDonald and Osuji (1995) and McMillen and McDonald (2004) showed evidence of "anticipative" effects, when residential land and housing price started to appreciate long before the completion of the new Midway Line stations in Chicago.

When the tradeoffs between accessibility convenience and neighborhood amenity of rail transit stations and the negative externalities of noise and crime are considered, Bollinger and Ihlanfeldt (1997) and Bowes and Ihlanfeldt (2001) found that the gross effects of rail transit externality vary by the proximity to downtown and also neighborhood income level; and the effects are not only dependent on distance to rail transit stations. Kilpatrick, Throupe, Carruthers and Krause (2007) showed negative externalities outweigh proximity benefits for houses that did not have direct access to stations, but were close to transit corridors. Market pricing for noise externalities could be distorted, if opposite externalities associated with rail noise could not be cleanly disentangled.

3. Background of KTM Railway lines and Operations

Keretapi Tanah Melayu (KTM), or Malayan Railway, a state-owned firm of Malaysia, has run the railway services between Malaysia and Singapore since 1923.[3] The ownership of KTM railway lands in Singapore could be traced as far back to the history of British's Straits Settlements that were made up of three colonial territories: Singapore, Malacca and Penang. The British colonial administrator, via the Singapore Railway Transfer Ordinance enacted on 25 October 1918, gave the right of use of approximately 200 hectares (ha) of lands in Singapore for KTM to run train services. The lands, varying from 15 meters to 55 meters in width, on both sides of the 40 km of rail tracks were leased to KTM on two different tenures, one for a period of 999 years and another for perpetuity (Figure 1).[4] Under the 1918 ordinance, the lands would have to be returned to the settlement's successor, Singapore, if the lands were no longer used for its intended purpose.

[Insert Figure 1 here]

The KTM train services were extended from Johor Bahru, the southernmost city of the Malayan peninsula, into Woodlands at the northern shore of Singapore island after the opening of the Causeway in 1923. The railway line was further extended to Tanjong Pagar in 1932, where the downtown railway station served as the last disembarkation point for KTM trains in Singapore. Customs, Immigration and Quarantine (CIQ) facilities of the two countries were cited side-by-side within the Tanjong Pagar station. Bukit Timah and Kranji stations were two other railway stations located between the Woodlands and Tanjong Pagar. Bukit Timah station served as the main intersection loop that facilitated the crossing of north-bound and south-bound trains.

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[3] Singapore was a part of Malaysia until it gained independence from Malaysia on 9 August 1965.
[4] Yang Razali Kassim, "New light on old issue," *Straits Times*, July 12, 2010.

On 27 November 1990, the then Prime Minister of Singapore, Mr Lee Kuan Yew signed an important agreement with the then Malaysian Finance Minister Tun Daim Zainuddin, which amended the KTM land rights under the 1918 ordinance. The agreement, which is referred to as the Point of Agreement (POA), if enforced, would require KTM to move its rail operations from Tanjong Pagar either first to Bukit Timah and later to Woodlands, or directly to Woodlands. The three railway stations (Tanjong Pagar, Kranji and Woodlands) and lands on both sides of the railway tracks would be returned to Singapore's government upon the cessation of the railway operations by the KTM. In return, Singapore's government allowed the three parcels of lands at Tanjong Pagar, Kranji, and Woodlands to be developed by a company jointly owned by Malaysia and Singapore.[5]However, the POA implementation was interrupted by the dispute of the Malaysian government on the omission of railway lands at Bukit Timah in the POA.[6]

In December 1998, the then Prime Minister of Malaysia, Dr Mahathir proposed to resolve the POA impasse by bundling together other bilateral issues, such as water supply and use of Malaysian airspace, as a package. Mr Lee Kuan Yew, in his capacity as the then Senior Minister of Singapore, negotiated and accepted the proposal made by the then Prime Minister Mahathir in 2001. However, the "package deal" approach was subsequently aborted by Malaysia's government in October 2002.

In May 2010[7], the two Prime Ministers, Mr Lee Hsien Loong of Singapore and Mr Najib Razak of Malaysia broke the two-decade POA impasse by sealing a landmark land-swop agreement, which paved the way for the move of the Tanjong Pagar railway station to the Woodlands' CIQ and Checkpoint. In the land-swop deal signed on 28 June 2011, the KTM lands at Tanjong Pagar, Kranji, Bukit Timah, and Woodlands, and the railway tracks would be returned to Singapore. In return, the Singaporean government would offer four parcels of land in Marina South (2.62 ha) and two parcels of land in Ophir-Rochor (2.67 ha) to M+S Private Limited, a

[5] Kor Kian Beng, "Points of agreement: A 20-year saga," *Straits Times*, May 25, 2010.
[6] Brendan Pereira and Irene Ng, "Thorny issues that go back many years," *Straits Times*, September 5, 2001.
[7] We use this date (May 2010) in which the agreement to enter into the land-swop deal between the two Prime Ministers was announced as the "announcement" date in our empirical design discussed in subsequent section.

joint-venture firm set owned by both countries' investment arms[8], which would undertake the developments of the lands.

On July 1, 2011, the KTM railway services in Singapore entered history books after the last KTM train pulled out of the Tanjong Pagar railway station at 11pm on June 30, 2011. This date marked "*a historic breakthrough in bilateral relations*" between the two countries as described by Singapore's Prime Minister, Mr Lee Hsien Loong on the announcement of the resolution of the railway lands issue.[9] KTM moved its railway terminal to the Woodlands Checkpoint in the northern part of Singapore, and lands along the railway tracks were returned to Singapore's government. Residents living close to the railway line could for the first time enjoy "*peace and quiet*", without KTM trains rumbling across their backyard after 80 years.

One issue in the POA relating to the impositions of development charges[10] on the KTM lands was unresolved, but the disagreement did not derail the implementation of the POA. The two governments referred the disputes to the Permanent Court of Arbitration at Hague.[11] The Hague's Arbitral Tribunal ruled against the imposition of development charges on the three KTM lands in Tanjong Pagar, Kranji, and Woodlands on October 31, 2014.[12] The decision put an end to the KTM railway lands dispute that had dogged the two countries for decades.

4. Data and Identification Strategy

We use non-landed housing transaction data for the period from January 2005 to June 2013 in our empirical tests. The data are obtained from the Realis database, a real estate information system managed by the Urban Redevelopment Authority (URA).[13] The

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8 M+S Private Limited is a joint venture company set up by the governments of Malaysia and Singapore to undertake developments of the lands in Marina South and Ophir-Rochor. The company has a 60% and 40% shareholding structure held by Malaysia's Khazanah Nasional and Singapore's Temasek Holdings, which are the investment arms of the two governments.

9 Zakir Hussain, "Tanjong Pagar station hangover; End of an era at Tanjong Pagar," *Straits Times*, 1 July 2011.

10 Development charges are a form development tax imposed by the Singapore's government on lands that are subject to change of use or intensification when planning permissions for development/ redevelopment are made.

11 The Shi Ning, "Land swap settles 20-year dispute," *Business Times Singapore*, September 21, 2010.

12 Angela Tan, "Court rules development charges for 3 former Malaya n Railway land in Singapore not payable," *Business Times*, October 31, 2014.

13 Urban Redevelopment Authority (URA) is a national planning authority of Singapore, which is entrusted with

non-landed residential properties samples include condominiums, apartments,[14] and executive condominiums.[15] The database contains transaction details captured in caveats lodged with the Singapore Land Authority,[16] which include information on transaction prices, dates of sale, and property attributes such as unit floor area, floor level, property type, lease tenure, and postal code. Figure 1 shows the map of railway track line and railway stations, which include Tanjong Pagar, Bukit Timah, Kranji and Woodlands Train Checkpoint.

Based on the 6-digit postal code[17] of each transaction, we measure the shortest (perpendicular) distance of housing samples to the railway line and various spatial and neighborhood characteristics using the GIS tool. As noise contour maps along the railway line are not available in Singapore, we use spatial discontinuity in housing prices to identify the cutoff distance for the railway-induced noise effects. We first split the areas up to 0.5km on both sides of the railway track into 10 discrete sub-areas (deciles) delineated by the contour lines of 0.05 km intervals, and test if price changes occur across different sub-areas controlling for observed housing and neighborhood attributes, time fixed effects (using the interactive month and year variable) and unobserved planning region and planning area fixed effects.

Based on the premise that noise levels are negatively correlated with distance of housing units from the railway track, we determine a cutoff distance upon which housing price changes are reversed from negative to positive with respect to distance from the KTM railway track as the cutoff boundary. This cut-off is then used to divide the study areas along the railway track into a rail noise externality zone and a rail noise neutral zone (areas that are affected by rail noise). Based on the spatial identification

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the responsibilities of master-planning the urban and infrastructure development for Singapore. It collects data on private property market transactions and publishes indices to track market trends in Singapore.

14 Condominiums and apartments are developed, built and sold in the open market by private developers. There are no restrictions on foreign ownerships for these two properties, except for apartment projects, where foreigners are only allowed to buy projects that are 6-storey and above in height. Condominiums could be sold freely in the open markets to foreigners.

15 The government introduced the executive condominiums (ECs) scheme in 1995. Like private non-landed housing, ECs are full-facilities public housing, but developed and sold by private developers to eligible buyers.[15] ECs are targeted at middle-income young professionals, who are subject to the income ceiling of S$12,000 per month.

16 Singapore Land Authority (SLA) is the custodian of state lands and national land registry of Singapore. A caveat is usually lodged with the SLA by a purchaser to protect his/her interest soon after an option to purchase a property is exercised or a sale and purchase agreement is signed.

17 In Singapore, a 6-digit postal code is used to represent a building block.

(the distance cutoff), we sort housing samples located within the rail noise externality zone into a treatment group and others into a control group. We also set two distances, which are 2km and 5km, as the outer boundaries in defining our study areas so as to avoid possible boundary discontinuity problems in our experiment design.

4.1. Descriptive Statistics

Table 1 summarizes the descriptive statistics of the key variables used in our study. Our samples consist of a total of 221,019 observations (transactions). The average transaction price of the samples was estimated at S$1,280,169, or an equivalent unit price of $11,025 per square meter (S$/psm). We convert the transaction prices into the logarithm term, and use the log-price as the response variable in our model. The average size of the samples was 116.51 square meter (sqm); and the average floor level of the sample transactions was estimated to be 9.49, which reflect the high-rise, high-density nature of housing developments in Singapore.

[Insert Table 1 here]

We define a set of dummy variables, which has a binary value of either 0 or 1, to represent housing type, land tenure and transaction type. We use two dummies: “condominium” and “apartment”, to represent the two housing types developed and sold by private developers. “Condominium” is a housing type that is usually of larger scale and equipped with full-fledged facilities within the development, compared with “apartments”, which is built on a smaller land parcel of less than 0.4 hectare. There is no restriction on foreigners’ purchases of “condominium”, but foreigners may only purchase “apartment” of above 6-storey heights under the Residential Property Act. Executive condominium (“EC”) projects also have the same facilities like private condominium projects, but they are built and sold by private developers on lands sold by the government. The ownership of ECs is restricted to only Singaporean citizens with monthly household income of less than S$12,000. We also use three dummy variables to separate transactions taking place at three different stages of the development processes, which include pre-completion units sold by developers (“New sale”); units by owners before completion (“Sub-sale”); and completed units sold in the secondary markets (“Resale”). “New sale” and “Resale” made up the majority of the transactions, which were estimated at 47% and 44%, respectively. We use “freehold” to represent housing units with tenure of more than 99 years, which is the common lease tenure for housing units built on state lands.

The average linear (perpendicular) distance of housing samples to the railway track was estimated at 6.6km. However, we use 2km and/or 5km as the upper boundaries to winsorize housing samples located outside the boundaries to avoid discontinuity in neighborhood characteristics that could affect the estimations (Black, 1999). We measure the closest distances to other amenities, such as MRT stations, bus stations, schools and the central business district (CBD). The statistics on means and standard deviations are reported in Table 1.

5. Empirical Design and Identification Strategy

We adopt a semi-log hedonic pricing model to empirically test the impact of noise reduction (removal) on residential property values. We rely on two types of variations as our identification strategy: proximity to KTM railway line (spatial variations), and before and after the cessation of KTM train services in Singapore (temporal variations).

Before estimating the impact of noise reduction due to KTM train service termination, we need to determine a threshold zone that separates houses that were affected by KTM train noise from those that were unaffected by the noise. In these analyses, we divide areas within 500 meters (m) of KTM railway lines into 10 sub-areas (deciles) with an equal-distance interval of 50m (i.e., 0-50m, 50-100m, … , 450-500m). We then estimate the price premium/discount for each sub-area using a hedonic pricing model:

$$lprice = \alpha + \sum_{i=1}^{10} \gamma_i D_{50(i-1)}^{50i} + \boldsymbol{X}'\beta + \boldsymbol{N}'\theta + \lambda + \tau + \varepsilon \quad (1)$$

where $lprice$ is the transacted property price in a log-term, $D_{50(i-1)}^{50i}$ indicates a subarea i located within $(50(i-1), 50i]$ meters to KTM railway lines (a linear perpendicular distance measure). γ_i is a price premium/discount estimated for housing in subarea i; β is a vector of coefficients for property characteristics, ***X'***, which include unit area, property type (apartment /condominium /executive condominium), land tenure (freehold/leasehold), sale type (resale/sub sale/new sale), and buyer type ("private buyer" has a value of 1, if a buyer currently lives in a private housing unit; and 0 otherwise, if he/she lives in a public housing unit); θ is a vector of coefficients for neighborhood amenities, ***N'***, which include distance to the nearest MRT station, distance to the nearest primary school, distance to the nearest shopping mall, distance to CBD area, and distance to the nearest bus stop; τ represents the year and month fixed effects, which account for price patterns in different years and seasonality within the same year; λ represents location fixed effects, where the two spatial measures including 38 planning areas, or 70 planning sectors identified by the first 2-digit postal code are used to control for unobserved spatial features at different neighborhood levels; ε is an *i.i.d.* error term.

We estimate Equation (1) using only transactions occurring before the announcement of the cessation of KTM services. The coefficients γ_1 to γ_{10} measure implicit pricing of the distance of housing units to the KTM railway line; and a negative coefficient indicates a price discount for being close to the KTM railway lines. Based on the distance coefficients, we identify the distance threshold when the coefficient changes from a negative value to a positive value. This distance threshold is used to sort sample houses into a treatment group consisting of houses that are negatively affected by train noise, and a control group with houses that are unaffected by train noise.

After delineating housing samples along the KTM railway lines into two groups[18], we investigate in the next step the impact of the removal of KTM railway noise by testing variations in prices of houses located "inside" and "outside" of the noise-affected areas, and "before" and "after" the cessation of the KTM railway operations. Two dates are used to identify the effects of the cessation of KTM railway operations in our models, which include the announcement date as on May 2010 ("*Afterannounce*") (when the two Prime Ministers announced the land-swop deal) and the implementation date as on July 1, 2011 ("*Afterimplement*") (when the train services

[18] The spatial boundary in our study serves the same purposes as the noise contours used in McMillen (2004) and others, as we expect that noise level is inversely correlated with distance from the railway tracks.

are terminated). We then extend the hedonic pricing model as follows:

$$lprice = \alpha + \rho_1 \times Afterannounce \times Treat + \rho_2 \times Afterimplement \times Treat + \rho_3 \times Treat + \boldsymbol{X}'\beta + \boldsymbol{N}'\theta + + \lambda + \tau + \varepsilon \quad (2)$$

where $Afterannounce$ is a time dummy variable that has a value of 1, if the date of transaction is after the announcement of the KTM cessation policy; 0 otherwise; and $Afterimplement$ is a time dummy used to identify transactions occurring after the implementation date. "*Treat*" is a spatial boundary dummy variable that has a value of 1, if a housing sample is located within the affected KTM noise zone; and 0 otherwise; ρ_1 and ρ_2 measure the impact of the removal noise externality on property values after the announcement and after the implementation of KTM POA, respectively. We expect the two coefficients to be positive, if people value quietness after train noise has been removed. Other variables in the model specification are the same as in equation (1). For both equation (1) and (2), the standard errors are clustered at the planning areas and/or the planning sectors (spatial fixed effects).

6. Main Results

6.1 Delineating Spatial Boundary (Treatment Zone)

Table 2 shows the estimation results of equation (1). As part of our boundary discontinuity design, we winsorize housing samples using outside 5 kilometers (columns 2 to 4) and 2 kilometers (columns 5 to 7). The models in column 2 and 5 are the most parsimonious regressions controlling only for property characteristics, year and month fixed effects and planning area fixed effects; while the models in column 4 and 7 are the most extended regressions that include property characteristics, neighborhood characteristics, year and month fixed effects, and postal district fixed effects.

[Insert Table 2 here]

The results are consistent with our expectations; the negative discrete distance coefficients indicate that properties that are closer to the KTM railway lines are priced at discounts compared to properties that are further away. We observe that the coefficients on the discrete distance variables change uniformly from a negative sign to a positive sign, when the distance to KTM railway line is greater than 400 meters. The results are consistent across all the six regressions suggesting that 400 meters is the clear discontinuity line that separates the affected and the unaffected KTM noise zones. Based on the maximum noise level model proposed by the US Federal Transit Administration (FTA) and a set of pre-determined parameters (as described in Appendix), the 400-meter distance is translated into a noise level of approximately 70 decibels to 84 decibels for a single passing train. There were about 10 trains passing by the KTM railway track a day before the operations ceased.

6.2 Impact of railway noise externalities on housing prices

Figure 2 plots the distributions of the monthly average of log-transacted price for houses located inside (treatment) and outside (control) the affected KTM noise areas. We observe significant price premiums for houses located outside the KTM noise zone before the announcement of the KTM railway service termination. However, the premiums decline, and turn negative (discounts) in some cases, after the announcement date indicating significant price appreciation for houses located in the affected areas after the removal of KTM noise externalities.

[Insert Figure 2 here]

Table 3 summarizes the empirical results on the impact of the termination of KTM rail operations on housing prices. The coefficients on "*Treat*" are significant and negative, which imply that noise externalities reduce housing prices by 6.1% to 8.1% (row 3) in the pre-termination period. However, after the announcement of the KTM land-swop agreement in May 2010, housing prices in the treatment areas increased significantly by 4.7% to 6.6% (row 4). Prices of the treated housing samples increased significantly by 12.1% to 14.7% (row 5) after the implementation of the KTM services termination agreement in July, 2011. We observe that housing price started to increase as soon as the KTM rail service termination was announced in May 2010, which was more than one year before the implementation of the agreement (July 2011). However, the earlier movers (sellers) did not fully cream off the abnormal profits associated with the removal of the noise externalities at the announcement date. Larger price capitalization effect was accrued to sellers, who waited and sold their houses after the implementation of the KTM termination agreement.

[Insert Table 3 here]

Compared to the discounts of 9.2% for the noise externalities in Chicago's O'Hare airport (McMillen, 2004), the price capitalization effects of at least 12.1% associated with the removal of the KTM noise externalities found in our results are equally substantial. Our results reaffirm that train noise externalities could adversely impact prices of houses located in close proximity to railway lines. Based on the aggregate values of S$2.97 billion for the post-implementation transactions of 2,322 sample houses in the treatment group and the lower bound of the housing price capitalization rate of 12.1%, we estimate that the KTM rail services cessation agreement generate realized economic benefits amounting to S$0.32 billion[19] for the Singaporean government.

7.3. Robustness Checks

7.3.1. Developer sales (new sales) versus private sales (re-sales)

Figure 3 shows the distributions of new sales and re-sales of private residential properties within the KTM noise zones (treatment groups). "New sales" by private developers consist mainly of housing units that are still under construction. "Resale" units are completed housing units sold by existing owners in the secondary markets. The share of resale properties within the affected KTM areas is larger than that of new sale properties. We test the impact of the removal of rail noise externalities on prices of new sale houses and resale houses, and the results are summarized in Tables 4 (new sale) and 5 (resale), respectively.

[Insert Figure 3 here]

We find that new sale houses gain more from the removal of the KTM noise

[19] Based on the capitalization rate of 12.1% and aggregated transacted housing value of S$2,97billion, the realized economic gain is computed as [S$2,97 × (0.121/1.121)] = S$0.32billion.

externalities in terms price appreciation compared to resale houses. The announcement of the KTM train services termination drove prices of new housing sales in the treatment areas up by 11.2% to 15.7%; while the announcement effects are also positive, but the magnitude of increase in resale housing prices in the treatment area is smaller at only 1.9% to 3.7%. The termination of KTM rail services on July 1, 2011 ("the implementation date") causes new sale housing prices in the treatment area to increase by 15.2% to 22.4%, and the "implementation" effects are three times stronger than price increases of 5.7% to 7.6% for resale housing units in the treatment area. The marginal treatment effects in the post-cessation of KTM rail services periods relative to the announcement periods were estimated at between 2.4% and 5.5% for the new sale properties; and between 3.8% and 4.4% for the resale properties.

[Insert Tables 4 and 5 here]

The differences in the capitalization effects of the removal of train noise externalities between new sales (developers' projects) and re-sales (owners' houses) have two possible implications. First, developers capitalize on the benefits associated with the removal of noise externalities into higher price premiums for their projects, compared to the houses sold by existing owners in the resale markets. Second, developers have also built in higher housing price premiums during the announcement periods in "anticipation" of the removal of noise externalities, and a smaller marginal increase in housing price was observed during the implementation periods. The "anticipative" premiums are relatively smaller for owner units sold in the secondary markets. The "anticipative" effects are also observed in the opening of the Midway Line in Chicago as shown by McDonald and Osuji (1995) and McMillen and McDonald (2004).

7.3.2. Noise externalities and distances from KTM rail lines

We conduct robustness tests to verify if our results are driven by different cut-off distances used to delineate the "treatment" areas (affected KTM rail noise areas). We substitute the 400 meters cut-off distance by two different threshold distances, which are 350 meters and 450 meters, and replicate the main empirical analyses. The results summarized in Tables 6 (350 meters) and 7 (450 meters) are largely consistent with the main findings in Table 3.

[Insert Tables 6 and 7 here]

The significance of the announcement effect decreases in the regressions, when the treatment boundary increases to 450 meters (Table 7). However, the results remain significant at the 5% level for the models with the complete set of control variables and fixed effects specifications (columns 4 and 7). The treatment effect has been weakened when the samples in the affected noise zone between 400 meters to 450 meters from the railway lines were added. However, we could not fully eliminate the externality effects associated with train noise on housing prices in the areas. Our results are robust to suggest that noise externalities associated with the KTM train operations are significantly and negatively correlated with distance of houses from the train lines.

7.4.3. Falsification tests using industrial properties

The cessation of KTM rail services is correlated with the removal of train noise in our empirical design. If this hypothesis does not hold, we should expect prices of houses in close proximity to the KTM train line to have no significant effects before and after the cessation of the KTM rail services. In our falsification tests, we collect transactions of industrial properties including factories and warehouses for the same sample period from the URA REALIS database. Based on the same 400 meters threshold, we find that 4.6 % of the industrial properties are located in the affected KTM noise areas (treatment group), and around 44.3% of the transactions occurred after the announcement of the KTM service termination. If users of factories and warehouses are not sensitive to train noise, we expect that the cessation of the KTM train services to have no significant impact on industrial property values.

Based on the same model specification as in equation (2), we estimate the model using industrial properties and summarize the results in Table 8. The results show no impact of the effects associated with the announcement and the implementation of KTM train service termination on industrial property prices. Our identification strategy of the train noise externality using the KTM rail service cessation event is robust; and the hypothesis that the removal of the KTM noise externalities is capitalized into the residential property prices is not rejected in our empirical tests.

[Insert Table 8 here]

7.4.4. *Building Height (Floor Level) Effects*

If train noise travels upward in a straight-line pattern, building height that measures the diagonal distance between buildings and railway lines could also explain price capitalization effects with respect to noise externalities. Given that trees and green buffers on both sides of the rail lines could reduce train noise, we expect high-floor housing units to experience stronger noise effects than low-floor housing units. In our robustness tests, we add an interactive term of the linear distance and the floor level ("Treat × Floor") to the models, and estimate the log-housing price functions using only pre-announcement samples. Table 9 shows that the "Floor" variable has positive coefficients indicating that high-floor units with unblocked views command premiums over low-floor units. However, the negative coefficients on the interactive term imply that the view premiums are *traded-off* by the negative impact of train noise that transmit directly to unblocked high-floor housing units located close to the train line. The price discounts were estimated at 6% to 8% for high floor units that are affected by the noise externalities of the KTM trains. The results are consistent with the evidence of the negative capitalization of noise externality in housing prices.

[Insert Table 9 here]

8. Conclusion

The 20-year impasse of the KTM railway line POA between Malaysia and Singapore has been amicably resolved via a landmark land-swop deal in May 2010. The deal led to the cessation of KTM railway services in Singapore; and as a result, KTM returned the railway lands at Tanjong Pagar, Bukit Timah, Kranji, and Woodlands stations and the accompanying lands along the 40km railway track cutting across the island to Singapore's government. The KTM train services were officially terminated on 1 July 2011, removing the noise externalities that have disrupted residents living in close proximity to the railway lines. This cessation of KTM railway services event offers clean and exogenous variations, spatially and temporally, for our quasi-experiment to test real estate capitalization effects associated with the removal of the train noise externalities.

Given that the KTM train line has been in operation for nearly 80 years on Singapore's lands since 1932 – long before many houses along the railway line were built – the removal event is clearly exogenous in our tests. As KTM trains are cross-border commuting services between Singapore and major cities in Malaysia, the close proximity to the railway train stations at Tanjong Pagar (the last disembarkation point in Singapore) is not likely to give significant accessibility benefits to local residents as in other rail transit stations studied in the US. Therefore, the distance measure used in our study is a clean proxy for noise externality.

We use non-landed housing transactions, in both private and public markets, in Singapore for the sample period from January 2005 to June 2013, and test the negative effects of noise externalities on housing prices. Using the cessation of KTM railway services as the exogenous shock, we found significant and positive effects on prices of houses located within 400 meters from the railway lines in the post-announcement periods (May 2010) and the post-implementation periods (July 2011) of the KTM cessation agreement. The early capitalization effects were estimated at between 4.7% and 6.6% when the KTM POA agreement was announced. The effects of the removal of the KTM noise were capitalized into housing prices by at least 12.1% in the post-implementation periods. We compute the realized economic benefits accrued to Singapore's government in the KTM service termination deal, which amounted to S$0.32 billion, based on estimated aggregate values of S$2.97 billion for sample houses transacted in the post-implementation period.

Our findings support the evidence in earlier literature that shows significant noise externalities associated with traffic noises. Our results are not affected by possible trade-off of accessibility benefits of rail transit lines, which could potentially bias downward the estimation of noise externalities. Unlike the opening of new rail transit lines and airports, the cessation of the KTM line event is unlikely to be affected by other cofounding effects such as traffic congestions, increased commercial activities, and employment, which are usually associated with the new and expanded airport and train facilities.

Appendix: *An engineering model on diffusion of noise generated by railway locomotive engines*

Noise emitted by passing trains is one of the most frequently experienced externalities by residents living close to railway lines (Dittrich 2001). The equivalent sound level (Leq) descriptor has been widely used by many countries to measure the noise impact from rail traffic. However, the maximum noise level (Lmax) has also been used as an alternative descriptor when sleep and health effects are considered (Zanetti 1996). The US Federal Transit Administration (FTA) estimate the maximum noise level (Lmax) for a single passing train (Harris Miller Miller & Hanson Inc., HMMH 1995) by adding noise from two different sources: locomotives and rail cars:

Noise from the locomotives:

$$L_{max,locos} = SEL_{locos} + 10\log\left(\frac{S}{50}\right) - 10\log\left(\frac{L}{50}\right) + 10\log(2\alpha) - 3.3 \quad \text{(A1)}$$

Noise from the rail cars:

$$L_{max,cars} = SEL_{cars} + 10\log\left(\frac{S}{50}\right) - 10\log\left(\frac{L}{50}\right) + 10\log[2\alpha + \sin(2\alpha)] - 3.3 \quad \text{(A2)}$$

The maximum noise level from a passing train:

$$L_{max,total} = \max[L_{max,locos}, L_{max,cars}] \quad \text{(A3)}$$

where SEL_{locos} and SEL_{car} are the reference sound exposal level (SEL) for a locomotive and a rail car at the reference distance of 50 feet and with the reference speed of 50 miles per hour, respectively; D is the closest distance between a receiver (resident) and the source, measured in feet; L is the total length of a referenced group of locomotive(s) or rail car(s) in feet; S is the vehicle speed in miles per hour; and $\alpha = \arctan(\frac{L}{2D})$, in radians.

Based on the assumptions that: (1) the length of a typical train consisting of a locomotive engine of 70 feet and six rail cars of 420 feet; (2) the average speed is 50 km/hour; and (3) the SEL_{locos} and SEL_{car} are set at 90DBA (a weighted decibel measure) and 82DBA, respectively, according to the HMMH (1995). The results suggest that the maximum noise level for a single train passing by the treatment area is computed at approximately between 70DBA and 84DBA. There were about 10 trains passing by the rail track on a daily basis before KTM ceased its Singapore's operations.

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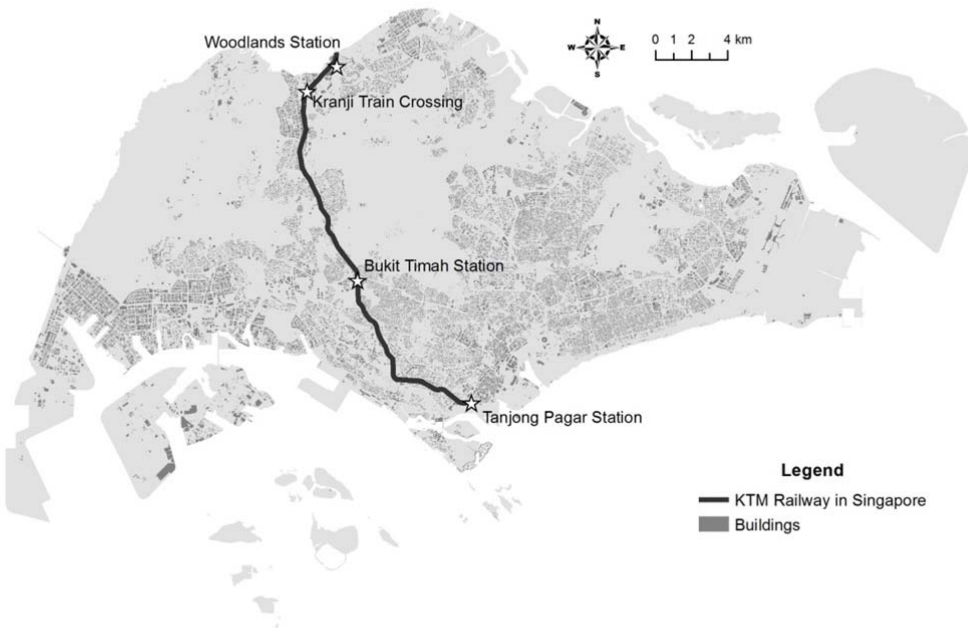
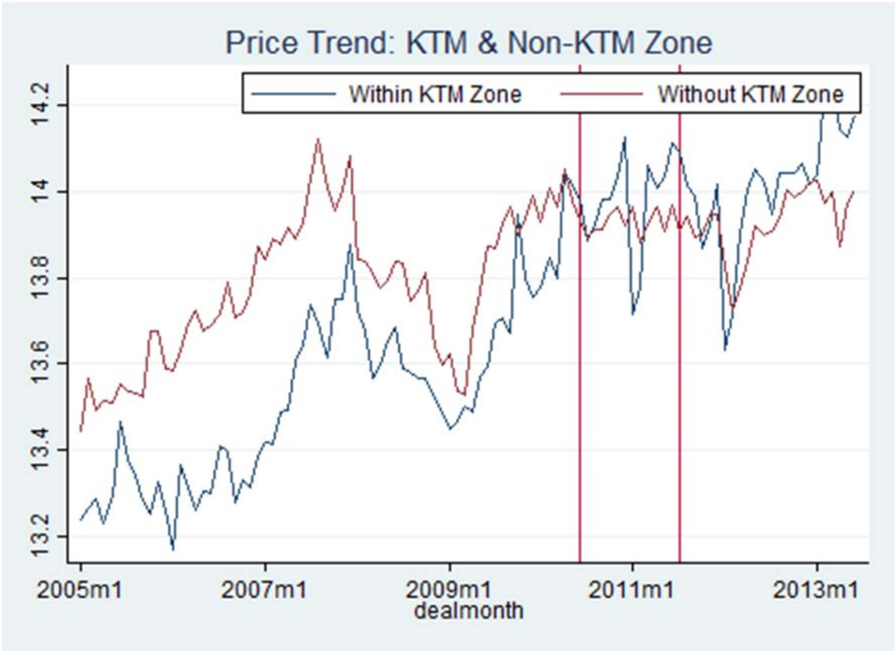
Figure 1: KTM Rail Line and Rail Stations in Singapore

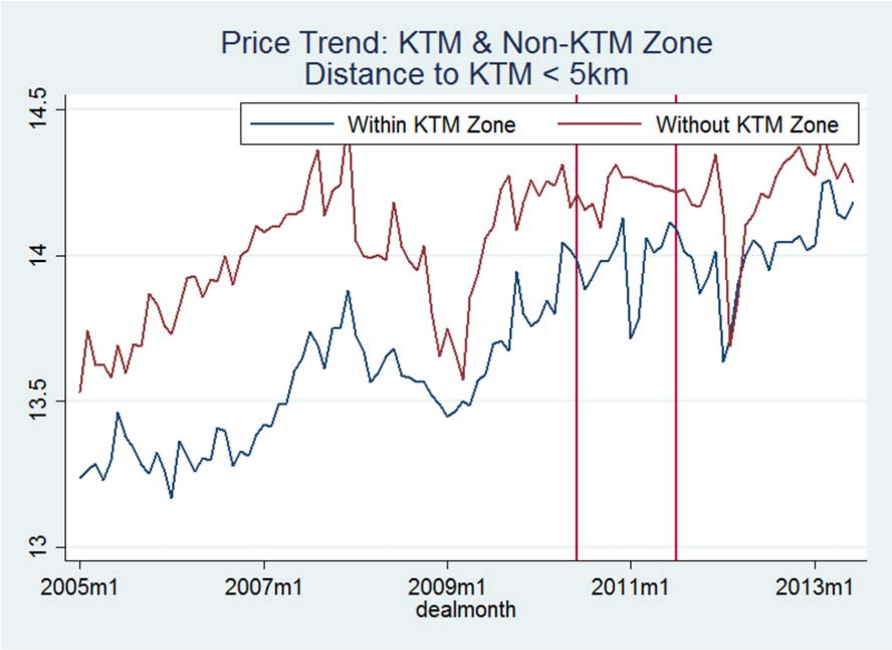


Note: The figure shows the Singapore island map with the darken line indicate the KTM railway tracks that starts at Woodlands station in the north and ends at Tanjong Pagar Stations in the south. The stations are represented by the "star" on the map. The other two stations are Bukit Timah Station and Kranji Train Crossing.

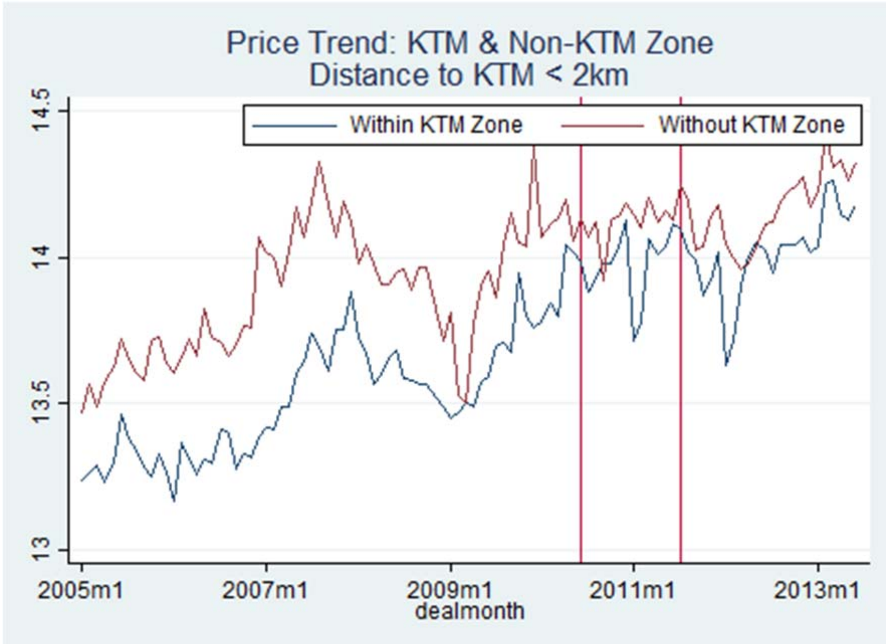
Figure 2. Price Trends of Properties Located Within and Outside KTM Noise Zones



(A) Full Sample



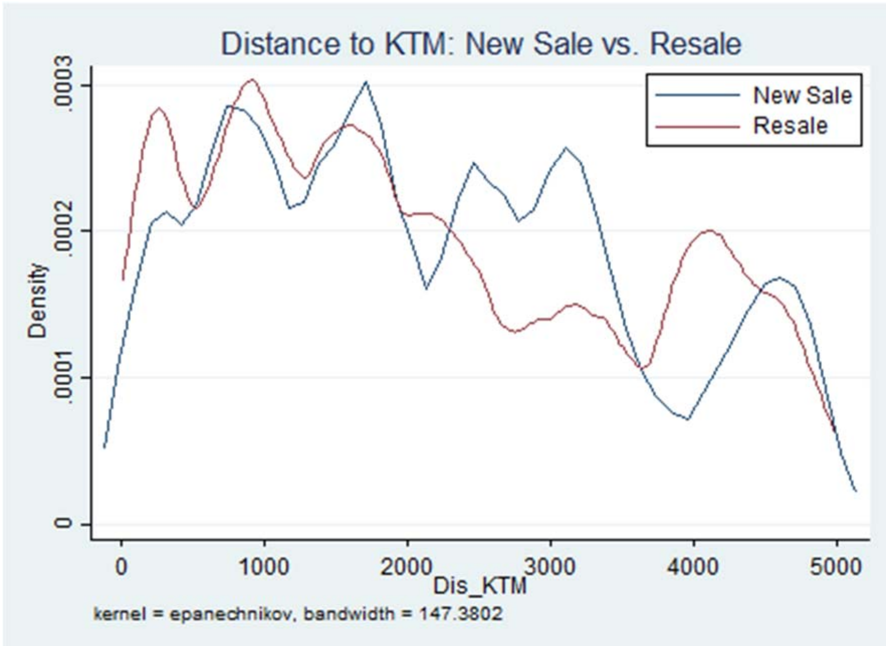
(B) Distance to KTM < 5km



(C) Distance to KTM < 2km

Note: The figure shows the price trends of housing transactions by month of the year. The blue line represents housing transactions in the "Treatment" area, which is less than 400 meter from the KTM railway line. The control group samples are represented by the blue line, which include houses outside the treatment zone. The sample period ranges from January 2005 to June 2013. The three figures above are plotted using different samples. (A) includes the full sample; (B) includes the housing samples that are located within 5km boundary from the railway track; and (C) includes the housing samples that are located within 2km boundary from the railway track.

Figure 3. Distributions of New Sale and Resale Housing Transactions



Note: The figure shows the kernel density plot of the number of housing transactions by distance to KTM railway line. The blue line represents "New Sale", which indicate pre-completion sales by private developers. "Resale" is represented by the red line, which shows the number of sales of completed housing units by owners. The cut-off boundary is set at 5km in the above graph.

Table 1: Summary of Statistics

Variable	Mean	Standard Deviation
A) Housing Attributes		
Transacted Price ($)	1,280,169	1,148,779
Unit price (per sqm)	11,025	5,548
Area (in sqm)	116.51	54.07
Floor Level	9.49	8.71
Dummy on Freehold	0.47	0.5
Dummy on Apartment	0.3	0.46
Dummy on Condominium	0.64	0.48
Dummy on EC	0.06	0.24
Dummy on New sale	0.47	0.5
Dummy on Sub-sale	0.1	0.29
Dummy on Resale	0.44	0.5
B) Distance to Local Amenities (km)		
Distance to KTM rail track	6.6	0.5
Distance to MRT station	6.62	0.79
Distance to primary school	7.14	0.61
Distance to CBD	8.83	0.75
Distance to bus station	4.88	0.66

Note: The table shows the descriptive statistics (mean and standard deviation) for the non-landed housing samples (including condominiums, apartments and executive condominiums). The full samples consist of 221,019 observations (transactions) are collected from Realis Database for the period from January 2005 to June 2013. Some of the housing samples are winsorized based on the distance to KTM rail track to avoid boundary discontinuity problems in the empirical analyses. The housing attributes are represented four parametric variables, such as transaction price, unit price, area and floor level, and also a group of binary dummy variables, which has a value of either 0 or 1. The distances to local amenities are measured using GIS tool.

Table 2. Determination of the Treatment Areas

Boundary to KTM railway line	Boundary Cutoff ≤ 5km			Boundary Cutoff ≤ 2km		
Distance to KTM railway line:						
[0-50m]	-0.046	-0.043	0.044	0.001	-0.002	0.084
	(0.051)	(0.053)	(0.063)	(0.053)	(0.055)	(0.059)
(50-100m]	-0.029	-0.034	-0.1	-0.027	-0.044	-0.07
	(0.025)	(0.027)	(0.038)***	(0.024)	(0.028)	(0.033)**
(100-150m]	-0.089	-0.095	-0.12	-0.094	-0.112	-0.106
	(0.027)***	(0.030)***	(0.028)***	(0.028)***	(0.028)***	(0.024)***
(150-200m]	-0.074	-0.075	-0.048	-0.07	-0.072	-0.055
	(0.046)	(0.047)	(0.054)	(0.044)	(0.046)	(0.047)
(200-250m]	-0.078	-0.073	-0.08	-0.07	-0.045	-0.036
	(0.036)**	(0.038)*	(0.037)**	(0.039)*	(0.051)	(0.042)
(250-300m]	-0.028	-0.037	-0.077	-0.036	-0.066	-0.063
	(0.036)	(0.037)	(0.044)*	(0.037)	(0.035)*	(0.044)
(300-350m]	0.017	0.013	-0.025	0.001	-0.026	-0.012
	(0.038)	(0.038)	(0.050)	(0.038)	(0.037)	(0.045)
(350-400m]	-0.056	-0.075	0.01	-0.053	-0.098	-0.044
	(0.025)**	(0.033)**	(0.036)	(0.022)**	(0.031)***	(0.037)
(400-450m]	0.185	0.192	0.106	0.176	0.157	0.103
	(0.116)	(0.116)*	(0.090)	(0.105)*	(0.101)	(0.078)
(450-500m]	0.107	0.108	0.022	0.113	0.09	0.027
	(0.042)**	(0.043)**	(0.038)	(0.044)**	(0.042)**	(0.035)
Area (sqm)	0.006	0.006	0.006	0.006	0.006	0.006
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Dummy on Condominium	0.213	0.214	0.151	0.203	0.207	0.178
	(0.018)***	(0.018)***	(0.022)***	(0.028)***	(0.028)***	(0.023)***
Dummy on EC	0.12	0.116	0.131	0.106	0.103	0.085
	(0.025)***	(0.025)***	(0.029)***	(0.036)***	(0.035)***	(0.032)***
Dummy on Freehold	0.094	0.094	0.126	0.145	0.144	0.172
	(0.017)***	(0.017)***	(0.022)***	(0.023)***	(0.025)***	(0.022)***
Dummy on Resale	-0.225	-0.227	-0.247	-0.26	-0.257	-0.249
	(0.014)***	(0.014)***	(0.016)***	(0.021)***	(0.020)***	(0.016)***
Dummy on SubSale	-0.081	-0.08	-0.068	-0.109	-0.12	-0.108
	(0.021)***	(0.018)***	(0.014)***	(0.039)***	(0.030)***	(0.021)***
Dummy on Private Buyer	0.082	0.08	0.073	0.072	0.063	0.051
	(0.005)***	(0.005)***	(0.005)***	(0.006)***	(0.005)***	(0.004)***
Year Fixed Effect	Y	Y	Y	Y	Y	Y
Month Fixed Effect	Y	Y	Y	Y	Y	Y
Neighborhood Characteristics	N	Y	Y	N	Y	Y
Planning Area Fixed Effect	Y	Y	N	Y	Y	N
Postal District Fixed Effect	N	N	Y	N	N	Y
R^2	0.86	0.86	0.85	0.82	0.83	0.86
N	67,201	67,201	67,201	31,529	31,529	31,529

*Notes: The table reports the statistics for the regression with log-transaction price as the dependent variable. The housing samples are winsorized at two boundary cutoffs: 5km and 2km, to minimize boundary discontinuity problems. The key variables are the linear distance to KTM railway line, where the distance between KTM railway line and 0.5km radius are divided into multiple discrete distances with an interval of 50 meter. We include the area (measured in square meter), and dummy variables that indicate different housing type: condominium, apartment and executive condominium (EC); sale types: resale, sub-sale, and the freehold dummy indicates land tenure of more than 99 years; and "private buyer" is a dummy of buyer type, where a value of 1 indicate a buyer with a private home address; and 0 otherwise, if a buyer has a public housing address. Neighborhood characteristics include distance to the nearest MRT station, distance to the nearest primary school, distance to the nearest shopping mall, distance to CBD area, and distance to the nearest bus stop; There are 38 planning areas and 82 postal districts in the data. Robust clustered standard errors at the postal code level. *** denotes p value < 0.01; ** denotes p value < 0.05; * denotes p value < 0.1.*

Table 3. Impact of KTM Removal on Housing Prices

Boundary to KTM railway line	**Boundary Cutoff ≤ 5km**			**Boundary Cutoff ≤ 2km**		
AfterAnnouce	-0.073	-0.075	-0.081	-0.085	-0.095	-0.079
	(0.014)***	(0.014)***	(0.014)***	(0.020)***	(0.019)***	(0.017)***
AfterImplement	-0.167	-0.165	-0.170	-0.172	-0.174	-0.165
	(0.022)***	(0.022)***	(0.022)***	(0.032)***	(0.033)***	(0.029)***
Treat	-0.061	-0.062	-0.081	-0.062	-0.075	-0.065
	(0.017)***	(0.018)***	(0.020)***	(0.017)***	(0.018)***	(0.019)***
Treat × AfterAnnounce	0.056	0.048	0.063	0.053	0.047	0.066
	(0.022)**	(0.026)*	(0.021)***	(0.024)**	(0.033)	(0.023)***
Treat × AfterImplement	0.123	0.121	0.147	0.123	0.124	0.135
	(0.029)***	(0.029)***	(0.026)***	(0.028)***	(0.028)***	(0.026)***
Area (sqm)	0.006	0.006	0.006	0.006	0.006	0.006
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Dummy on Condominium	0.201	0.202	0.153	0.185	0.184	0.161
	(0.018)***	(0.017)***	(0.018)***	(0.028)***	(0.026)***	(0.020)***
Dummy on EC	0.068	0.07	0.074	-0.012	0.005	-0.006
	(0.026)***	(0.026)***	(0.028)***	(0.033)	(0.033)	(0.031)
Dummy on Freehold	0.096	0.096	0.127	0.124	0.128	0.154
	(0.015)***	(0.015)***	(0.017)***	(0.020)***	(0.019)***	(0.018)***
Dummy on Resale	-0.199	-0.199	-0.215	-0.228	-0.223	-0.225
	(0.012)***	(0.011)***	(0.012)***	(0.017)***	(0.016)***	(0.013)***
Dummy on SubSale	-0.065	-0.067	-0.071	-0.069	-0.079	-0.093
	(0.017)***	(0.015)***	(0.012)***	(0.031)**	(0.025)***	(0.016)***
Dummy on Private Buyer	0.077	0.075	0.07	0.071	0.064	0.054
	(0.004)***	(0.004)***	(0.004)***	(0.005)***	(0.004)***	(0.003)***
Year Fixed Effect	Y	Y	Y	Y	Y	Y
Month Fixed Effect	Y	Y	Y	Y	Y	Y
Neighborhood Characteristics	N	Y	Y	N	Y	Y
Planning Area Fixed Effect	Y	Y	N	Y	Y	N
Postal District Fixed Effect	N	N	Y	N	N	Y
R^2	0.86	0.86	0.85	0.82	0.83	0.86
N	100,992	100,992	100,992	52,169	52,169	52,169

*Notes: The table reports the statistics for the regression with log-transaction price as the dependent variable. The housing samples are winsorized at two boundary cutoffs: 5km and 2km, to minimize boundary discontinuity problems. The treatment and event variables are represented by "Treat", which has a value of 1, if a house is located within 400 m from KTM railway line; and 0 otherwise; and "Afterannouce" is a time dummy that has a value of 1, if a transaction occurs in and after May 2010; and 0 otherwise; and "Afterimplement" is a time dummy that has a value of 1, if a transaction occurs in and after July 2011, the implementation of the KTM rail services cessation agreement. The two interactive variables: "Treat×Afterannounce" and "Treat×Afterimplement" are also included. We include other control variables: area (measured in square meter), and dummy variables that indicate different housing type: condominium, apartment and executive condominium (EC); sale types: resale, sub-sale, and the freehold dummy indicates land tenure of more than 99 years; and "private buyer" is a dummy of buyer type, where a value of 1 indicate a buyer with a private home address; and 0 otherwise, if a buyer has a public housing address. Neighborhood characteristics include distance to the nearest MRT station, distance to the nearest primary school, distance to the nearest shopping mall, distance to CBD area, and distance to the nearest bus stop; There are 38 planning areas and 82 postal districts in the data. Robust clustered standard errors at the postal code level. *** denotes p value < 0.01; ** denotes p value < 0.05; * denotes p value < 0.1.*

Table 4. Impact of KTM Removal on Housing Prices (New Sale)

Boundary to KTM railway line	Boundary Cutoff ≤ 5km			Boundary Cutoff ≤ 2km		
AfterAnnounce	-0.102	-0.096	-0.106	-0.104	-0.108	-0.087
	(0.033)***	(0.034)***	(0.034)***	(0.038)***	(0.034)***	(0.030)***
AfterImplement	-0.189	-0.188	-0.186	-0.16	-0.155	-0.149
	(0.046)***	(0.046)***	(0.049)***	(0.061)***	(0.055)***	(0.051)***
Treat	-0.126	-0.1	-0.125	-0.119	-0.112	-0.057
	(0.027)***	(0.029)***	(0.048)***	(0.028)***	(0.031)***	(0.040)
Treat × AfterAnnounce	0.157	0.131	0.112	0.145	0.114	0.138
	(0.039)***	(0.040)***	(0.047)**	(0.040)***	(0.040)***	(0.048)***
Treat × AfterImplement	0.183	0.155	0.224	0.181	0.152	0.193
	(0.057)***	(0.062)**	(0.067)***	(0.057)***	(0.062)**	(0.053)***
Area (sqm)	0.006	0.006	0.007	0.006	0.006	0.006
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Dummy on Condominium	0.178	0.173	0.119	0.194	0.2	0.192
	(0.023)***	(0.022)***	(0.024)***	(0.031)***	(0.027)***	(0.025)***
Dummy on EC	0.018	0.038	0.025	-0.038	-0.027	0.006
	(0.035)	(0.038)	(0.048)	(0.045)	(0.046)	(0.050)
Dummy on Freehold	0.03	0.036	0.111	0.063	0.086	0.164
	-0.025	-0.023	(0.029)***	(0.027)**	(0.025)***	(0.027)***
Dummy on Private Buyer	0.075	0.073	0.074	0.065	0.059	0.055
	(0.005)***	(0.005)***	(0.005)***	(0.006)***	(0.005)***	(0.005)***
Year Fixed Effect	Y	Y	Y	Y	Y	Y
Month Fixed Effect	Y	Y	Y	Y	Y	Y
Neighborhood Characteristics	N	Y	Y	N	Y	Y
Planning Area Fixed Effect	Y	Y	N	Y	Y	N
Postal District Fixed Effect	N	N	Y	N	N	Y
R^2	0.88	0.89	0.88	0.86	0.87	0.88
N	39,982	39,982	39,982	20,179	20,179	20,179

*Notes: The table reports the statistics for the regression with log-transaction price as the dependent variable. The housing samples are winsorized at two boundary cutoffs: 5km and 2km, to minimize boundary discontinuity problems. The treatment and event variables are represented by "Treat", which has a value of 1, if a house is located within 400 m from KTM railway line; and 0 otherwise; and "Afterannouce" is a time dummy that has a value of 1, if a transaction occurs in and after May 2010; and 0 otherwise; and "Afterimplement" is a time dummy that has a value of 1, if a transaction occurs in and after July 2011, the implementation of the KTM rail services cessation agreement. The two interactive variables: "Treat×Afterannounce" and "Treat×Afterimplement" are also included. We include other control variables: area (measured in square meter), and dummy variables that indicate different housing type: condominium, apartment and executive condominium (EC); sale types: resale, sub-sale, and the freehold dummy indicates land tenure of more than 99 years; and "private buyer" is a dummy of buyer type, where a value of 1 indicate a buyer with a private home address; and 0 otherwise, if a buyer has a public housing address. Neighborhood characteristics include distance to the nearest MRT station, distance to the nearest primary school, distance to the nearest shopping mall, distance to CBD area, and distance to the nearest bus stop; There are 38 planning areas and 82 postal districts in the data. Robust clustered standard errors at the postal code level. *** denotes p value < 0.01; ** denotes p value < 0.05; * denotes p value < 0.1.*

Table 5. Impact of KTM Removal on Housing Prices (Resale)

Boundary to KTM railway line	**Boundary Cutoff ≤ 5km**			**Boundary Cutoff ≤ 2km**		
AfterAnnounce	-0.06	-0.058	-0.05	-0.076	-0.073	-0.062
	(0.009)***	(0.008)***	(0.008)***	(0.011)***	(0.010)***	(0.009)***
AfterImplement	-0.123	-0.12	-0.108	-0.155	-0.147	-0.14
	(0.015)***	(0.014)***	(0.015)***	(0.018)***	(0.017)***	(0.016)***
Treat	-0.05	-0.05	-0.06	-0.047	-0.058	-0.059
	(0.021)**	(0.021)**	(0.021)***	(0.022)**	(0.021)***	(0.021)***
Treat × AfterAnnounce	0.037	0.033	0.031	0.033	0.03	0.019
	(0.013)***	(0.012)***	(0.014)**	(0.014)**	(0.013)**	(0.014)
Treat × AfterImplement	0.076	0.074	0.071	0.072	0.074	0.057
	(0.013)***	(0.013)***	(0.014)***	(0.016)***	(0.015)***	(0.014)***
Area (sqm)	0.005	0.005	0.005	0.005	0.005	0.005
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Dummy on Condominium	0.231	0.23	0.203	0.18	0.169	0.162
	(0.017)***	(0.017)***	(0.018)***	(0.023)***	(0.023)***	(0.022)***
Dummy on EC	0.116	0.109	0.119	0.079	0.08	0.074
	(0.021)***	(0.022)***	(0.023)***	(0.028)***	(0.031)***	(0.029)***
Dummy on Freehold	0.162	0.162	0.166	0.188	0.182	0.163
	(0.016)***	(0.015)***	(0.018)***	(0.020)***	(0.021)***	(0.021)***
Dummy on Private Buyer	0.062	0.06	0.054	0.057	0.052	0.042
	(0.004)***	(0.004)***	(0.004)***	(0.005)***	(0.005)***	(0.004)***
Year Fixed Effect	Y	Y	Y	Y	Y	Y
Month Fixed Effect	Y	Y	Y	Y	Y	Y
Neighborhood Characteristics	N	Y	Y	N	Y	Y
Planning Area Fixed Effect	Y	Y	N	Y	Y	N
Postal District Fixed Effect	N	N	Y	N	N	Y
R^2	0.85	0.85	0.86	0.82	0.84	0.86
N	49,122	49,122	49,122	26,116	26,116	26,116

*Notes: The table reports the statistics for the regression with log-transaction price as the dependent variable. The housing samples are winsorized at two boundary cutoffs: 5km and 2km, to minimize boundary discontinuity problems. The treatment and event variables are represented by "Treat", which has a value of 1, if a house is located within 400 m from KTM railway line; and 0 otherwise; and "Afterannouce" is a time dummy that has a value of 1, if a transaction occurs in and after May 2010; and 0 otherwise; and "Afterimplement" is a time dummy that has a value of 1, if a transaction occurs in and after July 2011, the implementation of the KTM rail services cessation agreement. The two interactive variables: "Treat×Afterannounce" and "Treat×Afterimplement" are also included. We include other control variables: area (measured in square meter), and dummy variables that indicate different housing type: condominium, apartment and executive condominium (EC); sale types: resale, sub-sale, and the freehold dummy indicates land tenure of more than 99 years; and "private buyer" is a dummy of buyer type, where a value of 1 indicate a buyer with a private home address; and 0 otherwise, if a buyer has a public housing address. Neighborhood characteristics include distance to the nearest MRT station, distance to the nearest primary school, distance to the nearest shopping mall, distance to CBD area, and distance to the nearest bus stop; There are 38 planning areas and 82 postal districts in the data. Robust clustered standard errors at the postal code level. *** denotes p value < 0.01; ** denotes p value < 0.05; * denotes p value < 0.1.*

Table 6. Impact of KTM Removal on Housing Prices (Affected Area: 350m)

Boundary to KTM railway line	Boundary Cutoff ≤ 5km			Boundary Cutoff ≤ 2km		
AfterAnnounce	-0.073	-0.075	-0.081	-0.084	-0.093	-0.079
	(0.014)***	(0.014)***	(0.014)***	(0.020)***	(0.019)***	(0.017)***
AfterImplement	-0.166	-0.164	-0.169	-0.169	-0.170	-0.161
	(0.022)***	(0.022)***	(0.023)***	(0.032)***	(0.032)***	(0.029)***
Treat	-0.058	-0.054	-0.088	-0.057	-0.059	-0.059
	(0.018)***	(0.019)***	(0.021)***	(0.018)***	(0.019)***	(0.019)***
Treat × AfterAnnounce	0.057	0.047	0.077	0.051	0.041	0.078
	(0.023)**	(0.028)*	(0.023)***	(0.025)**	(0.036)	(0.025)***
Treat × AfterImplement	0.124	0.120	0.154	0.123	0.118	0.139
	(0.031)***	(0.030)***	(0.029)***	(0.030)***	(0.030)***	(0.027)***
Area (sqm)	0.006	0.006	0.006	0.006	0.006	0.006
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Dummy on Condominium	0.201	0.203	0.153	0.187	0.187	0.163
	(0.018)***	(0.017)***	(0.018)***	(0.028)***	(0.026)***	(0.020)***
Dummy on EC	0.070	0.072	0.077	-0.010	0.008	-0.005
	(0.026)***	(0.026)***	(0.028)***	(0.034)	(0.033)	(0.032)
Dummy on Freehold	0.095	0.095	0.127	0.123	0.127	0.155
	(0.015)***	(0.015)***	(0.017)***	(0.019)***	(0.019)***	(0.018)***
Dummy on Resale	-0.199	-0.199	-0.216	-0.229	-0.225	-0.226
	(0.012)***	(0.011)***	(0.011)***	(0.017)***	(0.016)***	(0.013)***
Dummy on SubSale	-0.065	-0.067	-0.072	-0.069	-0.080	-0.094
	(0.017)***	(0.015)***	(0.012)***	(0.031)**	(0.025)***	(0.016)***
Dummy on Private Buyer	0.077	0.075	0.070	0.071	0.064	0.054
	(0.004)***	(0.004)***	(0.004)***	(0.005)***	(0.004)***	(0.003)***
Year Fixed Effect	Y	Y	Y	Y	Y	Y
Month Fixed Effect	Y	Y	Y	Y	Y	Y
Neighborhood Characteristics	N	Y	Y	N	Y	Y
Planning Area Fixed Effect	Y	Y	N	Y	Y	N
Postal District Fixed Effect	N	N	Y	N	N	Y
R^2	0.86	0.86	0.85	0.82	0.83	0.86
N	100,992	100,992	100,992	52,169	52,169	52,169

*Notes: The table reports the statistics for the regression with log-transaction price as the dependent variable. The housing samples are winsorized at two boundary cutoffs: 5km and 2km, to minimize boundary discontinuity problems. The treatment and event variables are represented by "Treat", which has a value of 1, if a house is located within 400 m from KTM railway line; and 0 otherwise; and "Afterannouce" is a time dummy that has a value of 1, if a transaction occurs in and after May 2010; and 0 otherwise; and "Afterimplement" is a time dummy that has a value of 1, if a transaction occurs in and after July 2011, the implementation of the KTM rail services cessation agreement. The two interactive variables: "Treat×Afterannounce" and "Treat×Afterimplement" are also included. We include other control variables: area (measured in square meter), and dummy variables that indicate different housing type: condominium, apartment and executive condominium (EC); sale types: resale, sub-sale, and the freehold dummy indicates land tenure of more than 99 years; and "private buyer" is a dummy of buyer type, where a value of 1 indicate a buyer with a private home address; and 0 otherwise, if a buyer has a public housing address. Neighborhood characteristics include distance to the nearest MRT station, distance to the nearest primary school, distance to the nearest shopping mall, distance to CBD area, and distance to the nearest bus stop; There are 38 planning areas and 82 postal districts in the data. Robust clustered standard errors at the postal code level. *** denotes p value < 0.01; ** denotes p value < 0.05; * denotes p value < 0.1.*

Table 7. Impact of KTM Removal on Housing Prices (Affected Area: 450m)

Boundary to KTM railway line	**Boundary Cutoff ≤ 5km**			**Boundary Cutoff ≤ 2km**		
AfterAnnounce	-0.073	-0.075	-0.08	-0.084	-0.094	-0.078
	(0.014)***	(0.014)***	(0.014)***	(0.019)***	(0.018)***	(0.016)***
AfterImplement	-0.165	-0.163	-0.168	-0.167	-0.171	-0.16
	(0.021)***	(0.021)***	(0.022)***	(0.029)***	(0.031)***	(0.028)***
Treat	-0.019	-0.02	-0.042	-0.022	-0.035	-0.028
	(0.036)	(0.036)	(0.030)	(0.034)	(0.033)	(0.027)
Treat × AfterAnnounce	0.032	0.026	0.049	0.031	0.027	0.052
	(0.029)	(0.030)	(0.023)**	(0.030)	(0.034)	(0.025)**
Treat × AfterImplement	0.094	0.094	0.123	0.094	0.097	0.111
	(0.034)***	(0.032)***	(0.028)***	(0.033)***	(0.031)***	(0.027)***
Area (sqm)	0.006	0.006	0.006	0.006	0.006	0.006
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Dummy on Condominium	0.201	0.203	0.153	0.188	0.186	0.163
	(0.017)***	(0.017)***	(0.018)***	(0.027)***	(0.026)***	(0.020)***
Dummy on EC	0.067	0.07	0.071	-0.015	0.004	-0.009
	(0.025)***	(0.025)***	(0.027)***	(0.032)	(0.032)	(0.030)
Dummy on Freehold	0.093	0.094	0.127	0.119	0.125	0.155
	(0.016)***	(0.015)***	(0.017)***	(0.021)***	(0.020)***	(0.018)***
Dummy on Resale	-0.2	-0.2	-0.218	-0.231	-0.227	-0.229
	(0.012)***	(0.012)***	(0.012)***	(0.018)***	(0.017)***	(0.014)***
Dummy on SubSale	-0.065	-0.068	-0.072	-0.069	-0.081	-0.095
	(0.017)***	(0.015)***	(0.012)***	(0.031)**	(0.025)***	(0.016)***
Dummy on Private Buyer	0.077	0.075	0.07	0.07	0.064	0.054
	(0.004)***	(0.004)***	(0.004)***	(0.005)***	(0.004)***	(0.004)***
Year Fixed Effect	Y	Y	Y	Y	Y	Y
Month Fixed Effect	Y	Y	Y	Y	Y	Y
Neighborhood Characteristics	N	Y	Y	N	Y	Y
Planning Area Fixed Effect	Y	Y	N	Y	Y	N
Postal District Fixed Effect	N	N	Y	N	N	Y
R^2	0.86	0.86	0.85	0.82	0.83	0.86
N	100,992	100,992	100,992	52,169	52,169	52,169

*Notes: The table reports the statistics for the regression with log-transaction price as the dependent variable. The housing samples are winsorized at two boundary cutoffs: 5km and 2km, to minimize boundary discontinuity problems. The treatment and event variables are represented by "Treat", which has a value of 1, if a house is located within 400 m from KTM railway line; and 0 otherwise; and "Afterannouce" is a time dummy that has a value of 1, if a transaction occurs in and after May 2010; and 0 otherwise; and "Afterimplement" is a time dummy that has a value of 1, if a transaction occurs in and after July 2011, the implementation of the KTM rail services cessation agreement. The two interactive variables: "Treat×Afterannounce" and "Treat×Afterimplement" are also included. We include other control variables: area (measured in square meter), and dummy variables that indicate different housing type: condominium, apartment and executive condominium (EC); sale types: resale, sub-sale, and the freehold dummy indicates land tenure of more than 99 years; and "private buyer" is a dummy of buyer type, where a value of 1 indicate a buyer with a private home address; and 0 otherwise, if a buyer has a public housing address. Neighborhood characteristics include distance to the nearest MRT station, distance to the nearest primary school, distance to the nearest shopping mall, distance to CBD area, and distance to the nearest bus stop; There are 38 planning areas and 82 postal districts in the data. Robust clustered standard errors at the postal code level. *** denotes p value < 0.01; ** denotes p value < 0.05; * denotes p value < 0.1.*

Table 8. Impact of KTM Removal on Industrial Properties (Falsification Test)

Boundary to KTM railway line	**Boundary Cutoff ≤ 5km**			**Boundary Cutoff ≤ 2km**		
AfterAnnounce	-0.015	-0.008	-0.02	-0.046	-0.036	-0.021
	(0.040)	(0.039)	(0.033)	(0.040)	(0.039)	(0.039)
AfterImplement	0.045	0.046	0.051	0.008	0.031	0.051
	(0.059)	(0.057)	(0.055)	(0.067)	(0.064)	(0.070)
Treat	0.454	0.526	-0.048	0.454	0.541	-0.037
	(0.137)***	(0.150)***	(0.168)	(0.104)***	(0.176)***	(0.206)
Treat × AfterAnnounce	0.056	0.038	0.056	0.072	0.058	0.007
	(0.070)	(0.067)	(0.066)	(0.062)	(0.060)	(0.055)
Treat × AfterImplement	0.028	0.011	-0.004	0.038	0.003	-0.063
	(0.069)	(0.068)	(0.074)	(0.073)	(0.069)	(0.073)
Year Fixed Effect	Y	Y	Y	Y	Y	Y
Month Fixed Effect	Y	Y	Y	Y	Y	Y
Property Characteristics	Y	Y	Y	Y	Y	Y
Neighborhood Characteristics	N	Y	Y	N	Y	Y
Planning Area Fixed Effect	Y	Y	N	Y	Y	N
Postal District Fixed Effect	N	N	Y	N	N	Y
R^2	0.51	0.51	0.52	0.62	0.62	0.63
N	9,875	9,875	9,875	5,128	5,128	5,128

*Notes: The table reports the statistics for the regression with log-transaction price as the dependent variable. The housing samples are winsorized at two boundary cutoffs: 5km and 2km, to minimize boundary discontinuity problems. The treatment and event variables are represented by "Treat", which has a value of 1, if a house is located within 400 m from KTM railway line; and 0 otherwise; and "Afterannouce" is a time dummy that has a value of 1, if a transaction occurs in and after May 2010; and 0 otherwise; and "Afterimplement" is a time dummy that has a value of 1, if a transaction occurs in and after July 2011, the implementation of the KTM rail services cessation agreement. The two interactive variables: "Treat×Afterannounce" and "Treat×Afterimplement" are also included. We include other control variables: area (measured in square meter), and dummy variables that indicate different housing type: condominium, apartment and executive condominium (EC); sale types: resale, sub-sale, and the freehold dummy indicates land tenure of more than 99 years; and "private buyer" is a dummy of buyer type, where a value of 1 indicate a buyer with a private home address; and 0 otherwise, if a buyer has a public housing address. Neighborhood characteristics include distance to the nearest MRT station, distance to the nearest primary school, distance to the nearest shopping mall, distance to CBD area, and distance to the nearest bus stop; There are 38 planning areas and 82 postal districts in the data. Robust clustered standard errors at the postal code level. *** denotes p value < 0.01; ** denotes p value < 0.05; * denotes p value < 0.1.*

Table 9. Price Premium for Floor Level: KTM and Non-KTM Zones

Boundary to KTM railway line	Boundary Cutoff ≤ 5km			Boundary Cutoff ≤ 2km		
Treat	-0.002	-0.011	-0.030	-0.007	-0.034	-0.039
	(0.018)	(0.020)	(0.023)	(0.021)	(0.019)*	(0.022)*
Level	0.003	0.004	0.005	0.003	0.003	0.003
	(0.001)***	(0.001)***	(0.001)***	(0.001)**	(0.001)***	(0.001)***
Treat * Level	-0.007	-0.008	-0.006	-0.007	-0.006	-0.003
	(0.002)***	(0.002)***	(0.002)***	(0.002)***	(0.002)***	(0.002)*
Area (sqm)	0.006	0.006	0.006	0.006	0.006	0.006
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Dummy on Condominium	0.203	0.202	0.149	0.186	0.191	0.173
	(0.020)***	(0.019)***	(0.021)***	(0.031)***	(0.030)***	(0.023)***
Dummy on EC	0.107	0.101	0.119	0.087	0.108	0.081
	(0.022)***	(0.023)***	(0.025)***	(0.031)***	(0.031)***	(0.027)***
Dummy on Freehold	0.096	0.094	0.136	0.145	0.144	0.18
	(0.018)***	(0.018)***	(0.020)***	(0.024)***	(0.024)***	(0.021)***
Dummy on Resale	-0.223	-0.225	-0.24	-0.263	-0.259	-0.246
	(0.014)***	(0.014)***	(0.015)***	(0.022)***	(0.021)***	(0.016)***
Dummy on SubSale	-0.082	-0.08	-0.07	-0.106	-0.118	-0.109
	(0.020)***	(0.018)***	(0.014)***	(0.038)***	(0.030)***	(0.019)***
Dummy on Private Buyer	0.083	0.081	0.073	0.074	0.064	0.051
	(0.005)***	(0.005)***	(0.004)***	(0.006)***	(0.006)***	(0.004)***
Year Fixed Effect	Y	Y	Y	Y	Y	Y
Month Fixed Effect	Y	Y	Y	Y	Y	Y
Neighborhood Characteristics	N	Y	Y	N	Y	Y
Planning Area Fixed Effect	Y	Y	N	Y	Y	N
Postal District Fixed Effect	N	N	Y	N	N	Y
R^2	0.86	0.86	0.86	0.82	0.83	0.86
N	67,188	67,188	67,188	31,519	31,519	31,519

*Notes: The table reports the statistics for the regression with log-transaction price as the dependent variable. The samples include only observations before the announcement period, i.e. housing samples that are affected by KTM noise externalities. The housing samples are winsorized at two boundary cutoffs: 5km and 2km, to minimize boundary discontinuity problems. The treatment variables are represented by "Treat", which has a value of 1, if a house is located within 400 m from KTM railway line; and 0 otherwise; and "Floor" is a continuous variable measuring the building height by the floor level of the housing samples. The interactive variable: "Treat×Floor" is also included. We include other control variables: area (measured in square meter), and dummy variables that indicate different housing type: condominium, apartment and executive condominium (EC); sale types: resale, sub-sale, and the freehold dummy indicates land tenure of more than 99 years; and "private buyer" is a dummy of buyer type, where a value of 1 indicate a buyer with a private home address; and 0 otherwise, if a buyer has a public housing address. Neighborhood characteristics include distance to the nearest MRT station, distance to the nearest primary school, distance to the nearest shopping mall, distance to CBD area, and distance to the nearest bus stop; There are 38 planning areas and 82 postal districts in the data. Robust clustered standard errors at the postal code level. *** denotes p value < 0.01; ** denotes p value < 0.05; * denotes p value < 0.1.*