ADBI Working Paper Series

HOW HIGH-SPEED RAIL AFFECTS LOCAL LAND PRICES: EVIDENCE FROM TAIPEI,CHINA

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No. 961
May 2019

Asian Development Bank Institute

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Suggested citation:

Renzhi, N. 2019. How High-Speed Rail Affects Local Land Prices: Evidence from Taipei,China. ADBI Working Paper 961. Tokyo: Asian Development Bank Institute. Available: https://www.adb.org/publications/how-high-speed-rail-affects-local-land-prices-evidence-taipei-china

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Abstract

This paper evaluates the effect of high-speed rail (THSR) on the land prices of targeted regions (THSR regions) in Taipei,China using prefectural-level data from 1993 to 2017. The construction of THSR started in 2000 and was finished in 2006. The THSR line to Zuoying (Kaohsiung City) first operated in 2007. After station construction for Miaoli, Changhua, and Yunlin was complete at the end of 2015, the entire line was open in 2016. THSR investment has been believed to play an important role in changing land usage and value, but such spillover effects on land prices have not yet been evaluated formally. Employing the difference-in-difference (DID) methodology, I estimate the impact of THSR on local land prices by comparing the land prices in THSR regions with those of other regions not covered by THSR. The results suggest that THSR positively affected the average land prices in THSR regions from the start of construction, and such positive effect became even larger after the beginning of the operation. There does, however, appear to be an inequality in land price growth among THSR regions. The positive spillover effects in northern regions are larger than those in their southern counterparts, which indicates that some straw effects may exist in southern regions. Because increases in local land prices often lead to increased local tax revenues, this paper, by showing the positive relationship between THSR investment and land prices, may have meaningful implications for future potential THSR investments in other economies or regions.

Keywords: high-speed rail, local land prices, transportation infrastructure

JEL Classification: L92, R41, R53, R58

Contents

1. INTRODUCTION

Transportation infrastructure, such as high-speed rail, has been widely considered a critical booster to economic development and an important contributor to technological innovation. This is one of the most engaging reasons why many economies invest significant public spending in the transportation sector.

High-speed rail—the fastest and most up-to-date railway system—has been treated as an elite symbol of national transportation development. It is also very expensive land-based transportation infrastructure. The construction cost of high-speed rail in Taipei,China (THSR) was about NT$513 billion, which means that the cost per route kilometer is about NT$14.9 billion. The huge expenditure required for high-speed rail projects makes it very difficult for policy makers to decide whether or not to adopt such investments, an issue that was faced by the government in Taipei,China. The THSR project was at first expected to be fully funded by the government, but this was rejected based on the huge costs and the uncertain potential project value, which led to a combination project including private investors. It is therefore vital to re-estimate the value of high-speed rail projects in a wide category that not only focus on its direct value—such as ticket revenues or the investment expenditure contributing to the local economy—but also the spillover effects such as increases in the local land value, which may indirectly boost the economy, because, in the long-term the project value of the THSR has been underestimated (Bowe and Lee 2004).

This paper uses local land prices to examine the spillover effects of the THSR and is perhaps the first empirical work that formally evaluates the impact of the THSR on local land prices. Land prices have been widely considered an indicator of future economic performance. Liu, Wang, and Zha (2013), using land as the firm' collateral when getting loans from the banks, have shown that land prices have a positive relationship with business investment. Renzhi (2018) has found that house prices (mostly determined by land prices) also have a positive impact on gross domestic product (GDP) by serving as an accelerator of unconventional monetary policy. Chen (2001) has also found that real estate prices (mostly determined by land prices) and stock prices play an important role in amplifying bank lending in Taipei,China. To show more evidence of the important role of land prices in the economy of Taipei,China, in this paper, I conduct a structural vector autoregression (VAR) model to estimate the effect of land-price movements on GDP. The results suggest that a 3.8% increase in land prices will lead to 2% growth in real GDP and this positive effect may last for one year. All of these findings provide firm evidence to show that studying the spillover effects of THSR on local land prices is of great importance.

To evaluate the impact of the THSR on local land prices, I employ a difference-in-difference (DID) approach. Specifically, I distinguish treated regions (regions with the THSR) from control regions (regions without the THSR) and compare the land-price movements of these two groups before and after three time periods related to the THSR: the construction period, the first operation period, and the second operation period. I also divide treated regions into "station located regions" and the "route-passing regions" (regions with stations or only routes, respectively). The baseline results show that the THSR contributes a 17.8% growth in local land prices in station located regions and a 19.9% increase in the route-passing regions during the first operation period, while in other time periods the positive effects of the THSR are also observed but are not statistically significant. This result is verified by the robustness check.

Regional analysis determined that there appear to be heterogeneous movements of local land prices in different parts of the treated regions. Specifically, I arranged the treated regions into North, Mid, and South to see the differences. The North region was greatly affected by the THSR, which contributed a 34.7% increase in local land prices for station located areas during the first operation and a 43% increase during the second operation. For the route-passing regions in the North region, the THSR contributed a 20.3% local land-price growth during the construction period, and this positive effect became even larger in the first operation period, with a 38.4% increase in land prices and 42.6% growth during the second operation period. There did not appear to be any significant increase in local land prices in the Mid and South regions resulting from the THSR, which is consistent with the results of Andersson, Shyr, and Fu (2010) who have pointed out the THSR only has a minor effect on house prices using data from the city of Tainan. This finding raises concern about potential existing "straw effects" caused by the THSR with a better connection to northern developed areas.

The remainder of the paper is organized as follows: section 2 describes the role of land prices in the macroeconomy; section 3 shows how high-speed rail affects land prices by presenting the detail of estimation approach, data, and results; and section 4 presents the conclusions.

2. LAND PRICES AND THE MACROECONOMY: THE EVIDENCE

The dynamic connections between house prices and the macroeconomy have been studied by many researchers in recent years. Iacoviello (2005) and Iacoviello and Neri (2010) have explained the positive co-movements between house prices and consumption expenditures by assuming households with credit constraints are using houses as collateral. Davis and Heathcote (2007), however, have provided evidence that house price movements are mainly driven by fluctuations in land prices instead of other factors such as construction costs. Based on this finding, Liu, Wang, and Zha (2013), using land as the firms' collateral when getting loans from the banks, have shown that land prices have a positive relationship with business investment. The transmission channel is simple: when land prices increase, driving up the collateral values of firms, which raises their borrowing capacity and makes more investment and consumption possible, leading to the growth in the economy.

2.1 The Structural VAR Model

In this subsection, I examine whether the above relationships of land prices and macroeconomy also exist in Taipei,China, based on a basic structural VAR model using aggregate semi-annual data series from September 1992 to March 2018. Let X_t be a 4×1 vector of endogenous random variables at time t, which consists of real GDP (y_t), the monetary aggregate (m_t), the interest rate (i_t), and aggregate real land prices (lp_t). Then, the model can be specified as follows:

$$X_t = A_0^{-1}A_1X_{t-1} + \cdots + A_0^{-1}A_pX_{t-p} + \varepsilon_t \quad (1)$$

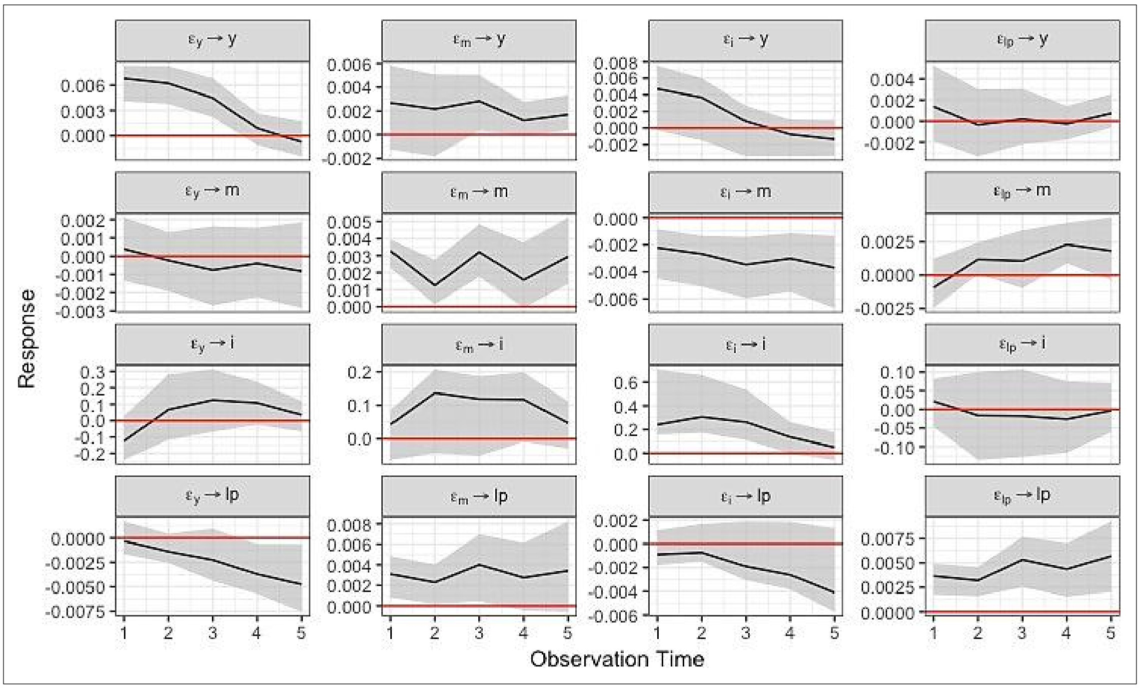
where $X_t = (y_t, m_t, i_t, lp_t)$, $A_0 - A_1L - \cdots - A_pL^p$ is the pth-order lag polynomial, and ε_t denotes the VAR residual vector that captures each structural shock of the endogenous variables.

The identification strategy I use is based on block recursive restriction (Christiano, Eichenbaum, and Evans 1999), with macroeconomic non-policy variables ordered first (y_t), followed by monetary policy variables (m_t and i_t), and finally monetary variables (lp_t). In this way, the structural VAR model can be identified by imposing the restriction that the monetary variables do not simultaneously affect macroeconomic variables.

2.2 Estimation of the Impulse Response Functions for the Structural VAR Model

The estimation results of the structural VAR model are presented in Figure 1, which shows the impulse responses to structural one-unit shocks in two standard error bands. The solid line denotes the estimated responses in levels over ten periods (five years) and the shaded areas enclose 95% confidence intervals calculated by Runkle's (1987) Monte Carlo simulation method.

Figure 1: Impulse Responses



Note: The shadow areas enclose 95% confidence intervals calculated by Runkle's (1987) Monte Carlo simulation method.
Source: Author's estimation.

First, I looked at the impulse responses to a positive land-price fluctuation as shown in the fourth column, which is the main objective of the estimation. When there is an increase in land prices, the real output shows a short-term rise, and the positive effect gradually disappears after one year (the fourth column, upper-row chart). Because the standard error bands of estimation for the impulse responses of real output are relatively tight, I can say that the results are reasonably meaningful. The estimation result also shows that a 3.8% increase in land prices will lead to a 2% growth in real GDP.

Then I considered the impulse responses of land prices to monetary policy variables: the monetary aggregate and the interest rate. An increase in the interest rate, indicating that a tight monetary policy shock has hit the economy, led to a persistent drop in land prices (the third column, bottom-row chart). This result indicates that a higher interest rate causes a fall in land prices by increasing the costs of financing land-related investment. An expansionary monetary aggregate generated a positive effect on land prices (the second column, bottom-row chart), which shows that a slack monetary policy will boost land markets by increasing money supply.

On the other hand, looking at the impulse responses of land prices to real output shock (the first column, bottom-row chart), there do not appear to be any positive effects of real output on land prices, but rather a negative effect, which is quite an interesting finding that calls for future investigation. In all, it appears that a positive shock to land prices has a short-term positive effect on real GDP. With such evidence, the important meaning of estimating the effects of THSR on local land prices is further enhanced.[1]

3. HOW DOES HIGH-SPEED RAIL AFFECT LOCAL LAND PRICES?

After showing the importance of land prices in affecting economic growth, in this section, I describe my empirical strategy, data, and the results of the impact on land prices resulting from the construction and operation of the THSR.

3.1 Institutional Background and Research Design

The island of Taipei,China features rugged central mountainous terrain that separates the island into the West Coast area and East Coast area. Although the West Coast area covers only half of the island, nearly 90% of the population is concentrated there. With high population density and rapid economic development, the demands for North–South intercity transportation has been increasing over the years, and an efficient high-speed mass transportation system is greatly needed. The THSR provides the best solution. This 349.5 km THSR route connects most of the main cities located in the West Coast area, and would make it possible to travel from Nangang to Zuoying (Kaohsiung) in only 2 hours, which greatly improves efficiency for intercity and regional daily commuting and business trips.

Transportation infrastructure investment has often played a key role in restructuring urban land usage and land price patterns in Taipei,China (Andersson, Shyr, and Fu 2010). To determine whether THSR has significant effects on local urban land prices, I employed an empirical strategy based on the DID approach, which allows the estimation of THSR's effect on land prices by comparing the difference between the land-price changes in regions with THSR and the land-price changes in regions without THSR. I divided the data samples into a treated group (regions with THSR) and a control group (regions without THSR) and split the time framework into pre-project and post-project.

[1] I also checked the robustness of my empirical results with several alternative frameworks by replacing the weighting matrix used in the estimation where I obtained similar impulse response results compared to those in the benchmark model. One of the test results is shown in Appendix A, while other results are omitted due to space constraints, but can be obtained on request.

The time-based comparison is made using the following framework: pre-construction covers the years before 2000, in the absence of THSR construction or operation. The design and construction period until the first phase of THSR operation to Zuoying covers the period from 2000 to 2006. The first phase of operation constitutes the period from 2007 and 2015, and the second phase of operation, when Miaoli, Yunlin, Zhanghua, and Nangang stations were open, includes the time period from 2016 until the present (Table 1).

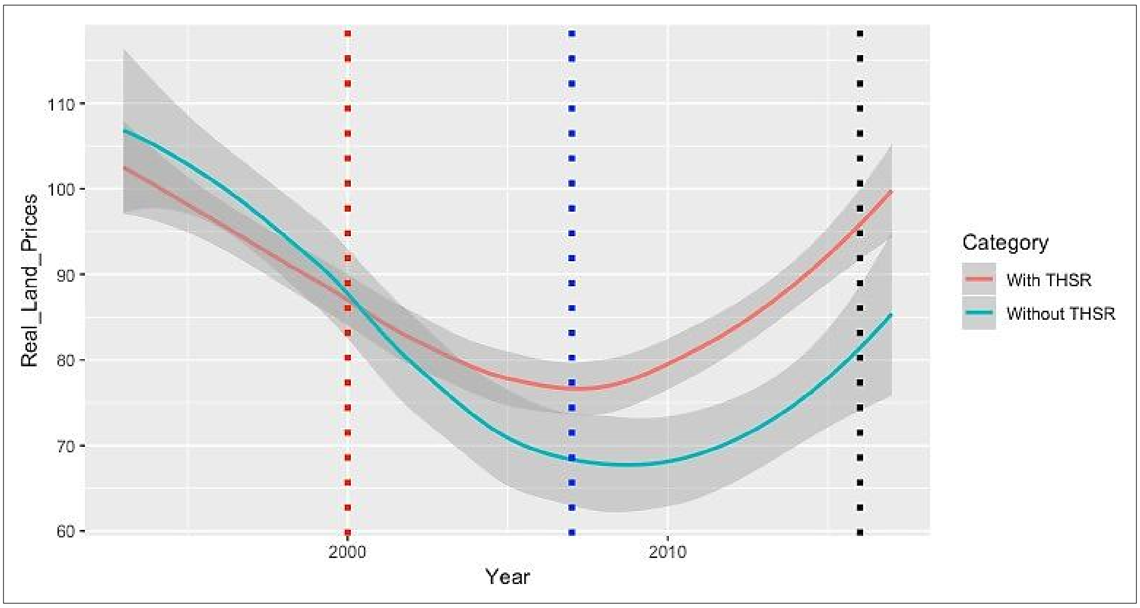
Table 1: The Construction and Operation Timeline of Taipei,China High-Speed-Rail

Period	Pre-construction	Construction	First Operation	Second Operation
Years	–2000	2000–2006	2007–2015	2016–

Source: THSR Corporation.

In Figure 2, I compare the average real land prices in the regions with THSR routes to the regions without a THSR route. Regions with THSR (treated region) include the 13 prefectures and cities that have THSR stations or route-passing. Regions without THSR (control regions) refer to those six prefectures and cities with no THSR stations or route-passing, including: Yilan Prefecture, Keelung City, Nantou Prefecture, Pingtung Prefecture, Taitung Prefecture, and Hualien Prefecture. Real land prices were calculated using the nominal urban land price index and the inflation rate (further details concerning data acquisition are covered in the data subsection). The red vertical line refers to the start of THSR construction in 2000, while the blue vertical line refers to the first operation of the THSR in 2007, and the black vertical line indicates the start of the second THSR operation in 2016.

Figure 2: Real Land Prices in Regions with THSR and Regions without THSR



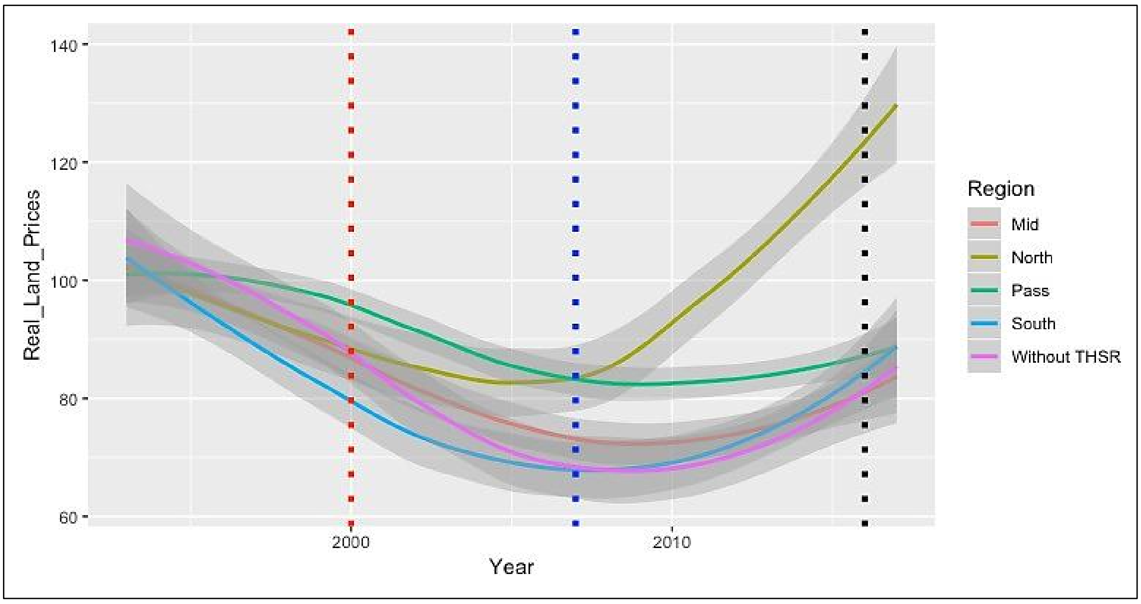
Note: Regions with THSR refer to those prefectures or cities have THSR stations or route-passing: Regions without THSR refer to those prefectures or cities have no THSR stations nor route-passing. The red vertical line refers to the start of THSR's construction in 2000. The blue vertical line refers to the start of THSR's first operation in 2007. The black vertical line refers to the start of THSR's second operation in 2016.

Source: Department of Land Administration, M.O.I, and author's calculation.

We can see that, before 2007, both regions had experienced a downward trend in real land prices, which was largely caused by the bust in the real estate market in early 1990. Land prices in regions without THSR had a relatively higher starting level, but after 2000, land prices in regions with THSR demonstrated a faster recovery and even showed an apparent higher increasing trend after 2007. This finding seems to be plausible because it may indicate there is a positive impact from THSR on local land prices even starting during the construction period.

The land price samples considered above may mask some heterogeneous factors behind the average number. I therefore rearranged the treated sample into four regional parts: North, Mid, South, and Passing. The “Passing regions” refer to those prefectures or cities that have no THSR stations but only routes passing through. Based on this new distinction, in Figure 3 we can see the land-price movements are totally different.

Figure 3: Real Land Prices in Regions with THSR and Regions without THSR (Regional)



Note: North region includes: Taoyuan City and Hsinchu Prefecture. Mid region includes: Miaoli Prefecture, Yunlin Prefecture, Changhua Prefecture, Taichung City. South region includes: Chiayi City, Tainan City, and Kaohsiung City. Pass region includes: Hsinchu City, Chiayi Prefecture. The red vertical line refers to the start of THSR’s construction in 2000. The blue vertical line refers to the start of THSR’s first operation in 2007. The black vertical line refers to the start of THSR’s second operation in 2016.

Source: Department of Land Administration, M.O.I, and author’s calculation.

Except for the North region, none of the other regions showed significantly higher land-price growth after construction of the THSR began. The North region is a relatively more developed area, economically, compared to the island as a whole. If most of the positive spillover effects on land prices from THSR only happen in the North region, rather than in other regions, the potential for a “straw effect” should not be neglected. This finding not only shows the importance of considering prefectural-specific factors in the estimation, but also the necessity of regional empirical analysis besides the all-prefecture analysis.

In sum, of the nineteen prefectures and cities, I employed thirteen as the treated group, and also divided this treated group into four sub-groups, North, Mid, South, and Pass, to assess regional differences. The control group includes the remaining six prefectures and cities that are not likely to be affected by the THSR.

3.2 Data

I used administrative statistics provided by the Statistics Offices in Taipei,China. Specifically, I obtained nominal prefectural-level land prices from the Urban Land Price Indexes (base-year=1993) provided by the Department of Land Administration, M.O.I. The prefectural-level data on household consumption were drawn from the annual report of the Survey of Family Income and Expenditure provided by the Statistical Bureau. The annual prefectural-level data on unemployment rates and population growth rates were also provided by the Statistical Bureau. The data on inflation rates used to calculate real variables using Consumer Price Indices (base-year=1993) were provided by the Statistical Bureau. The time series data on interest rates—to capture monetary policy changes—made use of Interbank Call Rates provided by the central bank.

Table 2: Descriptive Statistics

	Obs.	Mean	S.D.	Min.	Max.
All-Prefecture Sample (19)					
Real land prices (Index)	475	85.4	18.6	47.2	143.1
Unemployment rate (%)	475	3.8	1.2	0.8	12.1
Population growth rate (%)	475	0.9	8.4	–15.9	30.4
Real household consumption (NTD)	475	541,718	110,456	320,888	845,509
Interest rate (%)	25	1.6	2.4	0.1	6.9
Control-Prefecture Sample (6)					
Real land prices (Index)	150	82.0	21.8	47.2	133.7
Unemployment rate (%)	150	3.9	1.1	1	6
Population growth rate (%)	150	–2.4	5.0	–12.5	14.7
Real household consumption (NTD)	150	471,571	68,606	320,888	646,248
North-Prefecture Sample (5)					
Real land prices (Index)	125	94.8	17.8	63.5	143.1
Unemployment rate (%)	125	3.7	1.4	0.9	12.1
Population growth rate (%)	125	10.5	8.2	–15.9	30.4
Real household consumption (NTD)	125	669,251	96,034	456,662	845,509
Mid-Prefecture Sample (4)					
Real land prices (Index)	100	82.8	13.2	56.8	106.1
Unemployment rate (%)	100	3.6	1.2	1	5.9
Population growth rate (%)	100	2.9	8.4	–9.6	29.2
Real household consumption (NTD)	100	495,915	81,283	343,536	678,529
South-Prefecture Sample (4)					
Real land prices (Index)	100	82.7	15.1	54.0	109.8
Unemployment rate (%)	100	3.8	1.1	0.8	5.9
Population growth rate (%)	100	1.5	5.1	–9.8	18.2
Real household consumption (NTD)	100	523,441	63,707	351,535	623,350

Source: Department of Land Administration, M.O.I, Central Bank, and the Statistical Bureau and author's calculation.

I combined and harmonized the annual national and prefectural-specific datasets and constructed a panel covering all nineteen prefectures on the island from 1993 to 2017. This 25-year panel allowed me to observe the long-term effects caused by the THSR by yielding a sufficient number of years before and after the THSR project started. Table 2 presents descriptive statistics for all of the variables used in the analysis, categorized by regional groups.

3.3 The Model

3.3.1 Specification Using All-Prefecture Sample

I first estimated the spillover effects of THSR on land prices using the all-prefectural sample as the baseline. To check the spillover effects in different periods as shown in Table 1, I specified three time-binary variables, $T_{construction}$, T_{1st}, and T_{2nd}, which refer to the construction period, the first operation period, and the second operation period, respectively. To find the effect differences between THSR station-located regions and THSR route (passing) regions, I created two binary variables, $d_{station}$ and d_{route}. The DID estimation equations follow the traditional Card and Krueger (1994) form:

$$\ln LP_{it} = \gamma_i + \lambda_t + \delta\ (T_{construction} \cdot d_{station}) + X_{i't}\beta + \varepsilon_{it} \quad (2)$$

$$\ln LP_{it} = \gamma_i + \lambda_t + \delta\ (T_{1st} \cdot d_{station}) + X_{i't}\beta + \varepsilon_{it} \quad (3)$$

$$\ln LP_{it} = \gamma_i + \lambda_t + \delta\ (T_{2nd} \cdot d_{station}) + X_{i't}\beta + \varepsilon_{it} \quad (4)$$

$$\ln LP_{it} = \gamma_i + \lambda_t + \delta\ (T_{construction} \cdot d_{route}) + X_{i't}\beta + \varepsilon_{it} \quad (5)$$

$$\ln LP_{it} = \gamma_i + \lambda_t + \delta\ (T_{1st} \cdot d_{route}) + X_{i't}\beta + \varepsilon_{it} \quad (6)$$

$$\ln LP_{it} = \gamma_i + \lambda_t + \delta\ (T_{2nd} \cdot d_{route}) + X_{i't}\beta + \varepsilon_{it} \quad (7)$$

where $\ln LP_{it}$ is the log of real land prices, i refers to each prefecture or city, and t denotes period. $T \cdot d$ is the interaction term of two binary variables indicating whether the observation belongs to the treated group after given time periods. X_{it} is the vector of the control variables to lower the bias of the omitted variables, which include time-varying variables at the prefectural level such as population growth, real household consumption, and unemployment rate, and time-varying variables at the economy level such as the interest rate; γ_i is a time-invariant prefectural effect and λ_t is the year-specific effect that common across all prefectures; ε_{it} is the error term, which is assumed to be independent over time.

I based the selection of control variables on empirical findings and the availability of prefectural-level data. As I shown in section 2, economic growth variables such as real GDP are likely to affect land prices in Taipei,China, so including prefectural real GDP variables as control variables may be a good choice to lower omitted variable biases. However, because the economy of Taipei,China is rather compact, there are no official prefectural-level GDP statistics. Instead, I used the average real household consumption data as the proxy variable for prefectural-level real GDP. I also added the unemployment rate combined with real household consumption to serve as indicators of prefectural economic growth, which may affect land-price movement in addition to THSR projects. Demography is also an important factor in determining land-price movement (Poterba, Weil, and Schiller 1991), so I included the prefectural-level data for the population growth rate as the control variable. Based on the findings in section 2, national monetary policy fluctuations significantly affect land-price dynamics, so adding the interest rate variable to the control variable vector is essential as well. Details on the data sources appeared in the previous subsection.

It is important to keep in mind that long-term autocorrelated time series (for example, land prices) may generate inconsistent standard errors when employing DID methodology, as has been criticized by Bertrand, Duflo, and Mullainathan (2004). Following their approach—which has been widely adopted in the infrastructure evaluation literature, including by Yoshino and Abidhadjaev (2017)—I solved this problem by employing heteroscedasticity and autocorrelation consistent (HAC) standard errors that are clustered at the prefectural level.

3.3.2 Specification Using Regional Sample

To address the regional differences of the spillover effects of THSR on land prices, I re-estimated the model using regional treated group samples: north-prefecture sample, mid-prefectural sample, and south-prefectural sample (Table 2). The control group to be compared remained unchanged. The setting of the model is the same as the baseline version, and the DID estimation equations also use the same form as the baseline case:

$$\ln LP_{it} = \gamma_i + \lambda_t + \delta\,(T_{construction} \cdot d_{station}) + X_{it}'\beta + \varepsilon_{it} \tag{8}$$

$$\ln LP_{it} = \gamma_i + \lambda_t + \delta\,(T_{1st} \cdot d_{station}) + X_{it}'\beta + \varepsilon_{it} \tag{9}$$

$$\ln LP_{it} = \gamma_i + \lambda_t + \delta\,(T_{2nd} \cdot d_{station}) + X_{it}'\beta + \varepsilon_{it} \tag{10}$$

$$\ln LP_{it} = \gamma_i + \lambda_t + \delta\,(T_{construction} \cdot d_{route}) + X_{it}'\beta + \varepsilon_{it} \tag{11}$$

$$\ln LP_{it} = \gamma_i + \lambda_t + \delta\,(T_{1st} \cdot d_{route}) + X_{it}'\beta + \varepsilon_{it} \tag{12}$$

$$\ln LP_{it} = \gamma_i + \lambda_t + \delta\,(T_{2nd} \cdot d_{route}) + X_{it}'\beta + \varepsilon_{it} \tag{13}$$

where $\ln LP_{it}$ is the log real land prices, i refers to each prefecture or city, and t denotes period. $T \cdot d$ is the interaction term of two binary variables indicating whether the observation belongs to the treated regional group after given time periods. X_{it} is the vector of control variables; γ_i is the time-invariant prefectural effect; λ_t is the year-specific effect common across sample prefectures; and ε_{it} is the error term, assumed to be independent over time.

3.4 Estimation Results

This subsection contains my empirical results concerning how the THSR affected local land prices using whole sample and regional sample data. To that end, I compared the land prices during the construction period, the first operation period, and the second operation period to those during the pre-construction period.

3.4.1 Baseline Results

Table 3 reports the spillover effects of the THSR on land prices using the all-prefecture sample for all six specifications: each one with or without including route passing prefectures for the given time period.

Table 3: Baseline Results

	Real Land Prices:					
	Station Located			Route Passing		
	Construction	First Operation	Second Operation	Construction	First Operation	Second Operation
DID	0.045	0.178**	0.168	0.120	0.199*	0.191
	(0.071)	(0.087)	(0.109)	(0.079)	(0.106)	(0.121)
Unemployment	−0.019	−0.059**	−0.022	−0.016	−0.064**	−0.022
	(0.015)	(0.026)	(0.016)	(0.014)	(0.027)	(0.016)
Household Consumption	−0.047	0.264**	0.082	−0.066	0.300**	0.078
	(0.090)	(0.123)	(0.106)	(0.088)	(0.136)	(0.109)
Population Growth	−0.00004**	−0.00002	−0.003***	−0.00003**	−0.00002	−0.003**
	(0.00002)	(0.00002)	(0.001)	(0.00002)	(0.00002)	(0.001)
Interest Rate	0.102***	−0.044***	0.148***	0.104***	−0.045***	0.146***
	(0.028)	(0.015)	(0.037)	(0.028)	(0.016)	(0.040)
Constant	4.612***	1.557	2.633*	4.846***	1.144	2.716*
	(1.144)	(1.563)	(1.465)	(1.113)	(1.729)	(1.459)
Observations	266	342	171	266	342	171
R2	0.432	0.360	0.154	0.452	0.352	0.156

Note: Regressions estimate equation (2)–(7) where the treated group uses all-prefecture sample data. The pre-construction period refers to 1993–1999. DID captures the spillover effects on real land prices resulting from the THSR. HAC standard errors are reported in the parentheses. *p<0.1; **p<0.05; ***p<0.01.

Source: Author's estimation.

For the station located regions, the impact of the THSR on the local land prices was positive for all three time periods. During the first operation period (2007–2015), the THSR increased local land prices by 17.8%, with statistical significance at the 5% level. Regional-specific control variables such as real household consumption were wide-ranging and only statistically significant during the first operation period. Population growth was not as important as it is in theory and hardly had an effect on land prices. The unemployment rate was statistically significant at the 5% level during the first operation periods, which negatively affected the land prices, capturing the fact that a better economy leads to higher land prices. Other control variables such as the interest rate (representing monetary policy changes) also showed significant effects during all three time periods.

In the route-passing regions, the THSR showed more significant effects on local land prices during the first operation period with 19.9% (statistically significant at the 10% level) growth in land prices. Control variables that showed significance in explaining land-price changes were the same as those in the station located regions. The THSR therefore appeared to significant positive effects on local land prices both in the station located regions and the route passing regions during the first operation periods, while in other periods such effects did not appear.

3.4.2 Regional Results

Table 4 reports the spillover effects of the THSR on land prices using the North-prefecture sample for all six specifications that were same as the baseline case.

Table 4: Regional Results: North

	Real Land Prices:					
	Station Located			Route Passing		
	Construction	First Operation	Second Operation	Construction	First Operation	Second Operation
DID	0.133	0.347***	0.430***	0.203**	0.384***	0.426***
	(0.096)	(0.114)	(0.137)	(0.090)	(0.123)	(0.145)
Unemployment	−0.012	−0.052	−0.011	−0.006	−0.049	−0.007
	(0.014)	(0.032)	(0.014)	(0.011)	(0.030)	(0.010)
Household Consumption	−0.058	0.197	−0.081	−0.264*	0.016	−0.218
	(0.162)	(0.162)	(0.154)	(0.145)	(0.217)	(0.158)
Population Growth	−0.00003	−0.00002	−0.004	−0.0001***	−0.00005	−0.006**
	(0.00002)	(0.00003)	(0.003)	(0.00002)	(0.00003)	(0.002)
Interest Rate	0.112***	−0.049**	0.153***	0.117***	−0.048**	0.154***
	(0.042)	(0.020)	(0.050)	(0.041)	(0.019)	(0.046)
Constant	4.679**	2.472	4.715**	7.340***	4.833*	6.501***
	(2.074)	(2.100)	(2.193)	(1.805)	(2.808)	(2.131)
Observations	154	198	99	154	198	
R^2	0.409	0.397	0.324	0.471	0.405	

Note: Regressions estimate equation (8)–(13) where the treated group uses north-prefecture sample data. The pre-construction period refers to 1993–1999. *DID* captures the spillover effects on real land prices resulting from the THSR. HAC standard errors are reported in the parentheses. *p<0.1; **p<0.05; ***p<0.01.

Source: Author's estimation.

In the North region, the THSR had greater effects on local land prices in the station located areas comparing to baseline results, which shows that the THSR contributed to 34.7% increase in local land prices (statistically significant at the 1% level) during the first operation period and an even higher 43% (statistically significant at the 1% level) during the second operation period. For the route-passing areas in the North region, the THSR contributed to 20.3% local land-price growth during the construction period (statistically significant at the 5% level), and this positive effect became even larger in the first operation period with a 38.4% increase in land prices (statistically significant at the 1% level) and 42.6% growth during the second operation period. The larger increase in land prices observed during the second operation may have been affected by the newly built Nangang station. Control variables such as household consumption only showed significance in the route-passing regions during the construction period, and population growth only showed significance in the route-passing regions during the construction and second operation periods. Unemployment showed no significance in either the station located and the route passing areas during all periods. On the other hand, the interest rate had significant effects in both the station-located and route passing areas during all three periods.

Table 5 shows the impact of THSR on land prices in the Mid region. For both the station located and the route-passing areas, the THSR did not appear to have any significant effect during any of the three time periods. Although the new stations in the prefectures of Miaoli, Changhua, and Yunlin were completed in the second operation period, the THSR's effects on land prices become smaller compared to the effects during the first operation period. For the control variables, unemployment only showed a significant effect in the route-passing areas during the first operation period. Population growth only showed a significant effect in the station located areas during the construction operation period. Household consumption generally had no significant effect on land prices throughout the whole time period. The interest rate generated significant effects during most periods.

Table 5: Regional Results: Mid

	Real Land Prices:					
	Station Located			Route Passing		
	Construction	**First Operation**	**Second Operation**	**Construction**	**First Operation**	**Second Operation**
DID	–0.060	0.156	0.051	0.114	0.147	0.051
	(0.065)	(0.107)	(0.123)	(0.098)	(0.096)	(0.123)
Unemployment	0.006	–0.056	–0.020	0.016	–0.069**	–0.020
	(0.025)	(0.036)	(0.043)	(0.025)	(0.033)	(0.043)
Household Consumption	0.213	–0.093	–0.068	–0.260	–0.096	–0.068
	(0.154)	(0.218)	(0.245)	(0.168)	(0.185)	(0.245)
Population Growth	0.0001***	0.00005	–0.003	–0.00004	0.00003	–0.003
	(0.00004)	(0.0001)	(0.004)	(0.00003)	(0.00003)	(0.004)
Interest Rate	0.156***	–0.034	0.136**	0.145***	–0.038*	0.136**
	(0.055)	(0.024)	(0.055)	(0.041)	(0.022)	(0.055)
Constant	6.383***	6.151**	4.679	7.045***	6.281***	4.679
	(1.924)	(2.751)	(2.972)	(2.118)	(2.355)	(2.972)
Observations	140	180	90	140	180	
R^2	0.507	0.425	0.284	0.511	0.438	

Note: Regressions estimate equation (8)–(13) where the treated group uses north-prefecture sample data. The pre-construction period refers to 1993–1999. *DID* captures the spillover effects on real land prices resulting from the THSR. HAC standard errors are reported in the parentheses. *p<0.1; **p<0.05; ***p<0.01.

Source: Author's estimation.

Finally, Table 6 presents the impact on land prices in the South region resulting from the THSR. Similar to the Mid region, there was no statistically significant effect in either the station located or route passing areas. For the control variables, the interest rate showed significant effects on land prices during the construction and second operation periods. Population growth showed significant effects in the station located areas during the construction and the second operation period, as well as in the route-passing areas during the construction period. Unemployment had significant effects on land prices during the first operation period. Other explanatory variables such as household consumption only showed a significant effect on land prices in the route-passing areas during the construction period.

In all, the regional results suggest that the positive effects brought by the THSR in the baseline model were mostly driven by the significant effects from the North region. There do not appear to have been any significant impact on land prices from the THSR in either the Mid or South regions, which largely explains why the whole sample results are not as plausible as in the case of the North region. This finding also raises the concern of "straw effects" caused by the THSR in the Mid and South regions because the local benefits from the THSR mainly flowed to the North region.

Table 6: Regional Results: South

	Real Land Prices:					
	Station Located			Route Passing		
	Construction	First Operation	Second Operation	Construction	First Operation	Second Operation
DID	0.023	0.073	0.122	0.100	0.108	0.094
	(0.098)	(0.130)	(0.133)	(0.091)	(0.117)	(0.133)
Unemployment	−0.007	−0.072**	−0.033	−0.002	−0.071**	−0.033
	(0.020)	(0.031)	(0.026)	(0.019)	(0.029)	(0.024)
Household Consumption	−0.232	−0.026	−0.078	−0.240*	−0.077	−0.114
	(0.162)	(0.208)	(0.195)	(0.123)	(0.183)	(0.163)
Population Growth	0.0001***	0.00001	0.006*	0.0001***	0.00000	0.005
	(0.00003)	(0.00005)	(0.003)	(0.00003)	(0.00005)	(0.004)
Interest Rate	0.153***	0.043	0.127**	0.161***	0.042	0.126**
	(0.046)	(0.028)	(0.057)	(0.044)	(0.027)	(0.054)
Constant	6.701***	5.408**	4.917**	6.738***	6.073***	5.389***
	(2.032)	(2.651)	(2.204)	(1.521)	(2.321)	(1.837)
Observations	140	180	90	140	180	90
R^2	0.523	0.414	0.298	0.551	0.422	0.293

Note: Regressions estimate equation (8)–(13) where the treated group uses north-prefecture sample data. The pre-construction period refers to 1993–1999. *DID* captures the spillover effects on real land prices resulting from the THSR. HAC standard errors are reported in the parentheses. *p<0.1; **p<0.05; ***p<0.01.

Source: Author's estimation.

3.5 Robustness Test

In this subsection, I conducted the robustness test by adding region-specific linear time trends to my DID models to examine whether or not the common trends assumption was problematic.[2] If the common trends assumption holds, there is smaller or less significant impact from the THSR on local land prices during the time periods before the start of a given period. Thanks to the long-term time series of my data, I can estimate the 6-year pre-project effect. More specifically, I checked the effect of the THSR on land prices during the periods 1994–1999 (pre-construction), 2001–2006 (pre-first-operation), and 2010–2015 (pre-second-operation), while the influence of other control variables remained unchanged. Within the time period 1994–1999, no THSR spillover effect existed, because the construction of the THSR had not started. During the period 2001–2006 (pre-first-operation), the THSR remained under construction, so the change in local land prices should be weaker compared to the baseline model results. During the period 2010–2015 (pre-second-operation), the THSR had already seen its first operation, which may not show a weaker effect compared to the baseline case, and therefore I expected a higher growth in land prices will be observed.

2 In this paper, I only present the robustness test for the baseline model to save space; robustness test results for the regional analysis were similar.

Table 7 reports the DID coefficients specified by time period dummy variables. The foot of the *DID* means a given year dummy for each time period, which refers to $DID_{construction, first\ operation, second\ operation}$. We can see that the effect of the THSR on land prices was weaker or less significant compared to the construction and first operation periods in the baseline model. THSR had a larger or a more significant impact on land prices compared to the second operation in the baseline case, which is the result I expected. The robustness check therefore confirmed that my estimation results for the spillover effects of the THSR on local land prices were reliable.

Table 7: Robustness Test

	Station Located			Route Passing		
	Construction	First Operation	Second Operation	Construction	First Operation	Second Operation
*DID*1999,2006,2015	0.039	0.169**	0.177	0.111	0.195*	0.198
	(0.068)	(0.085)	(0.109)	(0.078)	(0.105)	(0.120)
*DID*1998,2005,2014	0.040	0.161*	0.184*	0.108	0.190*	0.204*
	(0.066)	(0.084)	(0.105)	(0.077)	(0.103)	(0.115)
*DID*1997,2004,2013	0.039	0.153*	0.188*	0.101	0.187*	0.208*
	(0.063)	(0.083)	(0.101)	(0.075)	(0.102)	(0.110)
*DID*1996,2003,2012	0.028	0.146*	0.187*	0.087	0.183*	0.210**
	(0.060)	(0.082)	(0.098)	(0.073)	(0.101)	(0.106)
*DID*1995,2002,2011	0.030	0.141*	0.184*	0.070	0.176*	0.209**
	(0.062)	(0.079)	(0.094)	(0.072)	(0.099)	(0.101)
*DID*1994,2001,2010	0.020	0.133*	0.167*	0.043	0.169*	0.185*
	(0.064)	(0.077)	(0.090)	(0.075)	(0.097)	(0.100)

Note: The treated group uses all-prefecture sample data. *DID* captures the spillover effects on real land prices resulting from the THSR. HAC standard errors are reported in the parentheses. *p<0.1; **p<0.05; ***p<0.01.

Source: Author's estimation.

4. CONCLUDING REMARKS

In this paper, I evaluated the spillover effects from the THSR on local land prices. To highlight the important role of land-price movements in the economic growth of Taipei,China, I adopted a structural VAR analysis that gives empirical evidence that a 3.8% land-price growth leads to a 2% increase in real GDP.

With this empirical finding, I followed the DID approach to estimate the effect of the THSR on local land prices in the station located and route-passing regions. I also differentiated the time periods into construction, first operation, and second operation periods to check the different impacts from the THSR during these different periods. The results of the baseline model using all-prefecture data indicate that the THSR significantly increased the local land prices in the station located regions by 17.8% during the first operation. These positive effects were even larger in the route-passing regions, where a 19.9% increase in local land prices was observed during the first operation period. Despite the lack of statistical significance, positive impacts on local land prices from the THSR were also estimated, and the robustness test proves that the estimation results are reliable.

To observe the heterogeneous performance of land-price movement that may be masked by the all-prefecture estimation, I also employed a regional analysis by dividing the THSR affected areas into North, Mid, and South regions in addition to the baseline whole sample results. The analysis results suggest that the THSR had a significant effect on local land prices in the North region that was larger than the baseline results, while there was no statistically significant increase in the Mid and South counterparts. This may indicate the regional inequality of land-price movements resulting from the THSR, which raises the concern of “straw effects” that potentially occurred in the Mid and South areas. Policy makers should carefully consider this issue if there are any future plans for extending the THSR route to the eastern areas of Taipei,China. In conclusion, I have provided evidence of the positive impact of the THSR on local land prices while the growth of land prices had heterogeneous movements among regions.

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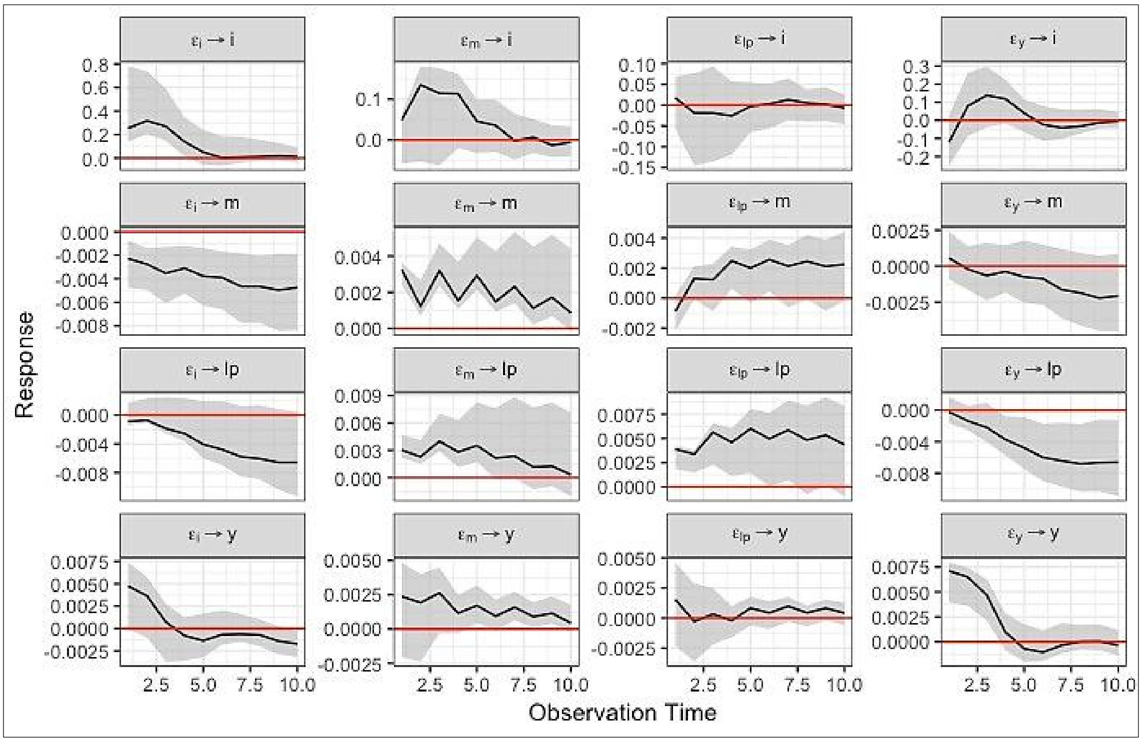
APPENDIX A

Impulse Responses: Robustness Check by Changing Weight Matrix



Note: The shadow areas enclose 95% confidence intervals calculated by Runkle's (1987) Monte Carlo simulation method.
Source: Author's estimation.